COVID-19 Impact on Agricultural Practices in Moldova

RfP n.0007 – Final presentation

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Agenda

Introduction – Valeria Donzelli (e-GEOS)
Service 1 - Paul Farrell (Mallon Technologies)
Service 2 – Cristina Monaco (Ithaca)
Conclusion and exploitation – Livio Rossi (e-GEOS)

The TEAM

E-GEOS

Italian global player in the Earth Observation, Remote Sensing and Geo-Spatial Information market

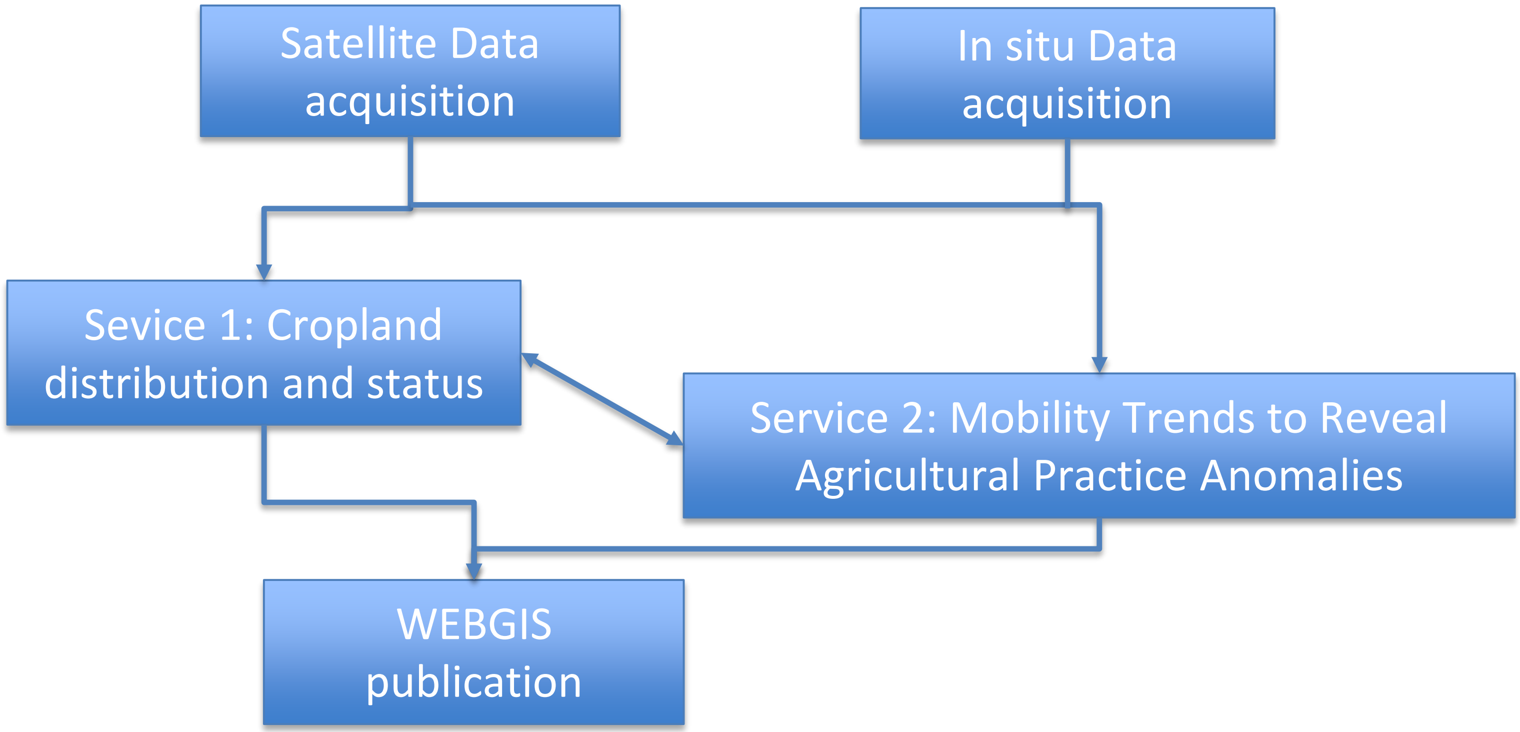
Mallon Technology

Irish SME providing Geo-Spatial solutions, Land Cover and Earth Observation (EO) services

ITHACA

Italian applied research centre devoted to support humanitarian activities in response to natural disasters by means of Geomatics techniques

Work FLOW


Satellite Data acquisition
In situ Data acquisition
Sevice 1: Cropland distribution and status
Service 2: Mobility Trends to Reveal Agricultural Practice Anomalies
WEBGIS publication

Objectives

- Service 1 “Cropland Distribution and Status” aimed at contributing to the monitoring of the agricultural activities and the estimation of the impact of COVID-19 on the local agricultural practices
- Service 2 “Mobility Trends to Reveal Agricultural Practice Anomalies” Service 2 activities were devoted to highlight possible spatial correlation between Covid-19 impact on population and anomalies detected on vegetation
- Work performed included final publication via an online visualization portal

Service 1: Introduction

- **Aim**: provide additional evidence on the recent events investigating historical and current EO data
- **Study area**: Falesti, Ungheni, Balti and Singerei *raion*
- **Study period**: January 2017 – June 2020
- **Service Output:** Yearly maps at 10 m resolution
  - Crop area extent
  - Season Start layer (by month)
  - Season Peak layer (by date)
  - Season End layer (by month)
  - Maximum greenness

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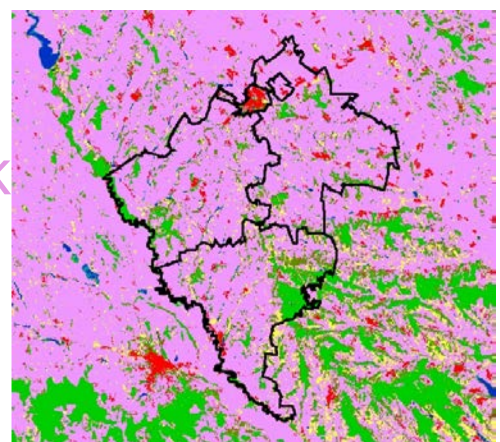
Service 1: Rationale

- **Aim**: provide additional evidence on the recent events investigating historical and current EO data
- Arable crop activities follow standard procedures and events such as:
  - **Sowing**
  - **Growing**
  - **Harvesting**
- EO data can detect evidences of these activities
- Historical data can be compared to current year

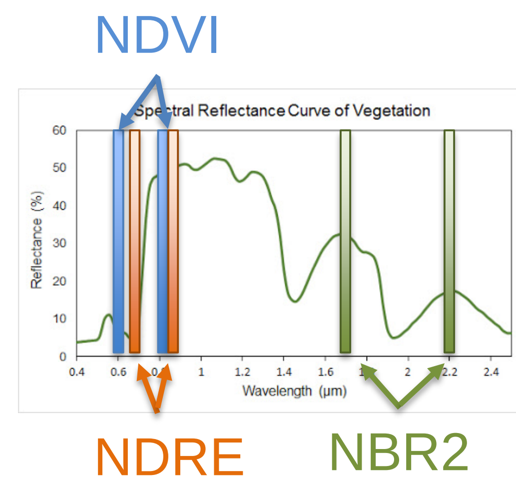
Service 1: Input data

- Copernicus ESA Sentinel 2 Multi-Spectral Imagery (MSI) L2A products – Surface Reflectance
  - 1 acquisition every 5 days minimum
    - All acquisitions with <30% cloud cover
- Copernicus Global Land Cover (CGLC)
- Agricultural areas in (pink



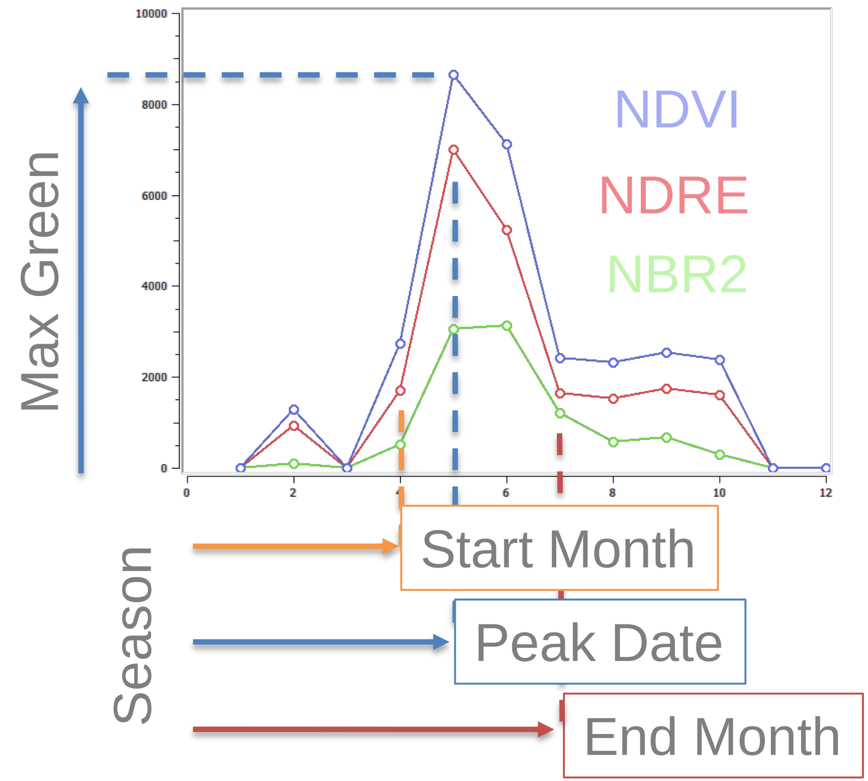
Service 1: Input data

- Sentinel 2 Reflectance data in ‘bands’
- Sentinel 2 Vegetation Indices (VI)
  - NDVI - Normalized Difference Vegetation Index
  - NDRE - Normalized Difference Red Edge
  - NBR2 - Normalized Burn Ratio version 2
- VI more robust to illumination conditions
- Designed for vegetation analysis
- Each index uses different target properties



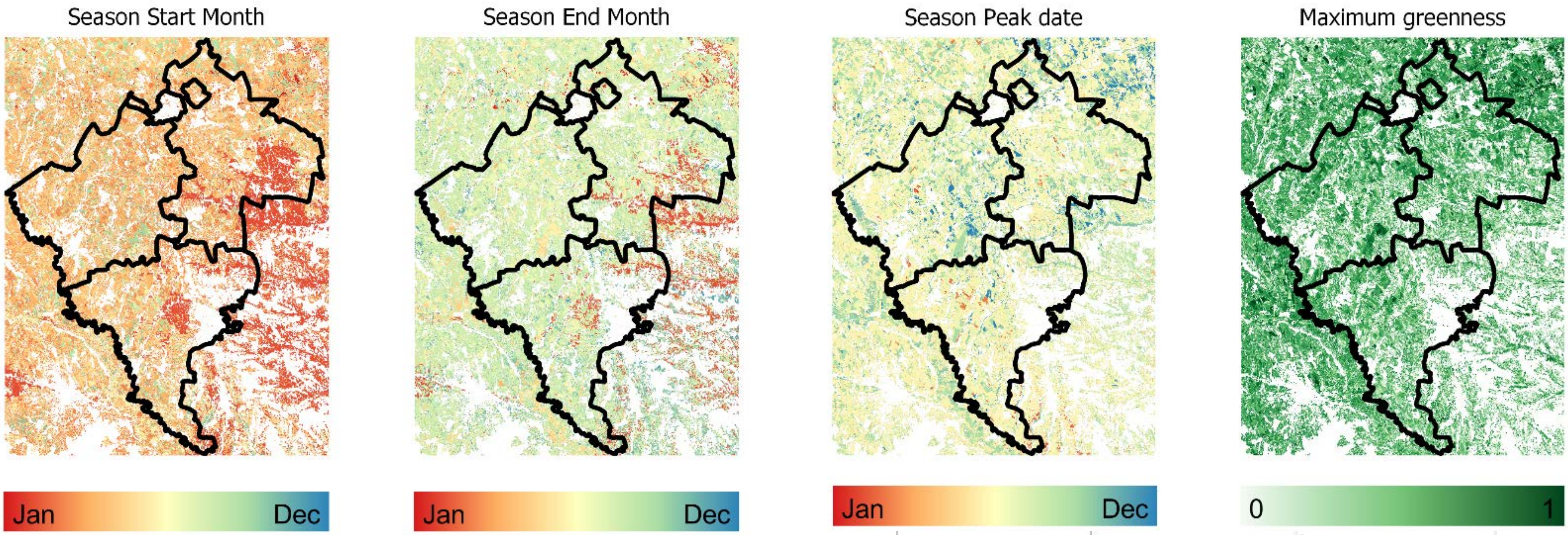
Service 1: Output

- Arable land extent map
  - Based on Land Cover layer and Vegetation Indices
- Crop Status
  - Growing Season Start
  - Growing Season Peak
  - Growing Season End
  - Maximum Greenness
- All raster layers are computed yearly within the AOI



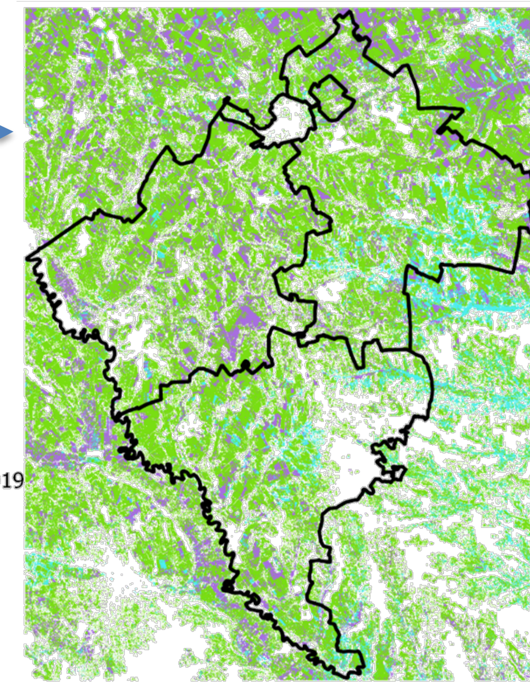
Service 1: 2017-2019 Results

- Season characterization
  - Start, Peak, End of season
- Maximum Greenness



Service 1: 2017-2019 Results

- Arable land extent mask
  - Confidence checks based on temporal consistence
  - Further quality check: Harvesting evidence layer
- Excludes non vegetated land, forested area, water and build-up



EO Clinic Service 1

AOI_LC

AOI

Output

CropMasked.2017

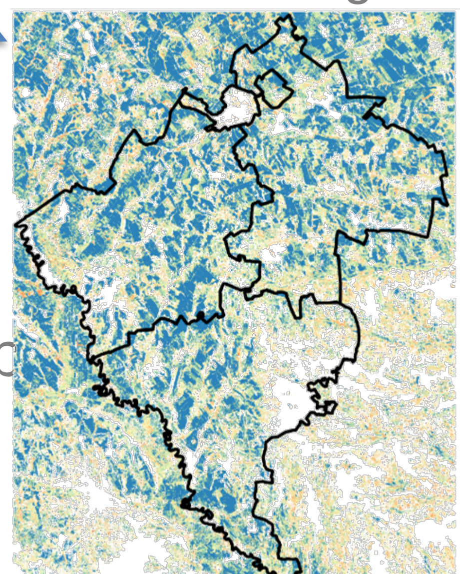
High Confidence

Mid Confidence

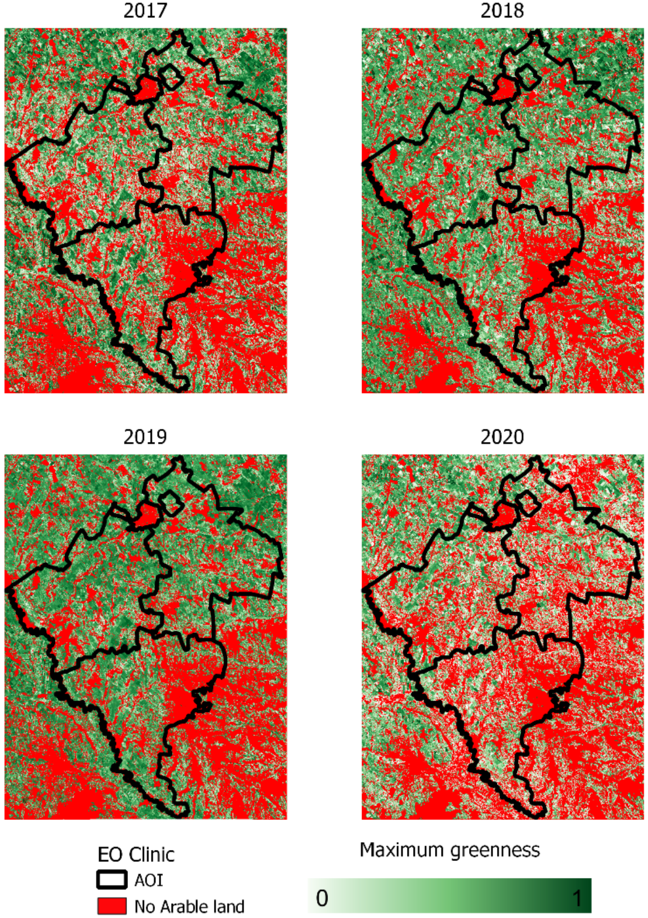
Low Confidence

Harvesting Confidence 2019

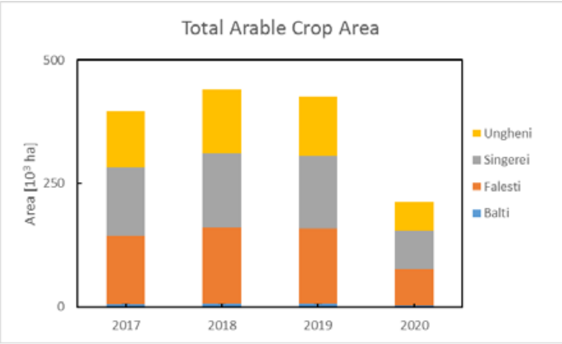
0, 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1

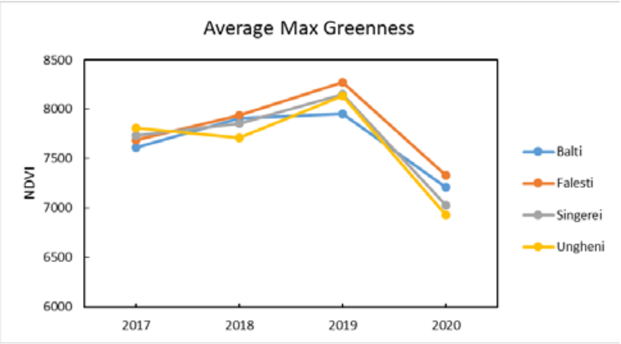


Service 1: 2020 comparison



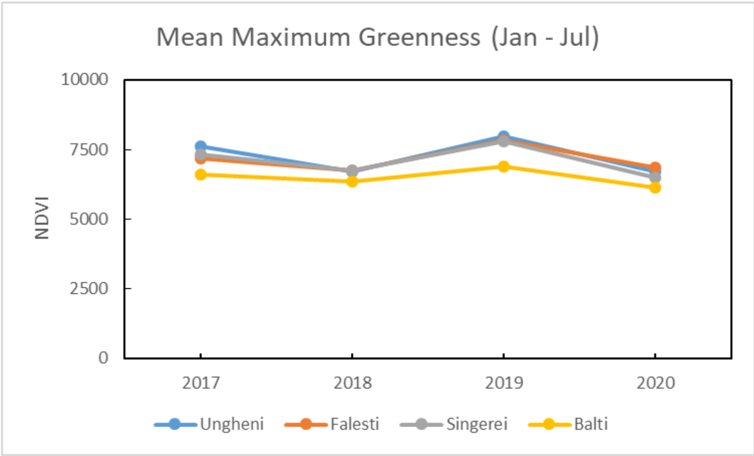
- Total arable crop extent decreased
- Maximum Greenness decreased
- Limitation: 2020 analysis up to July and lack of reference data.

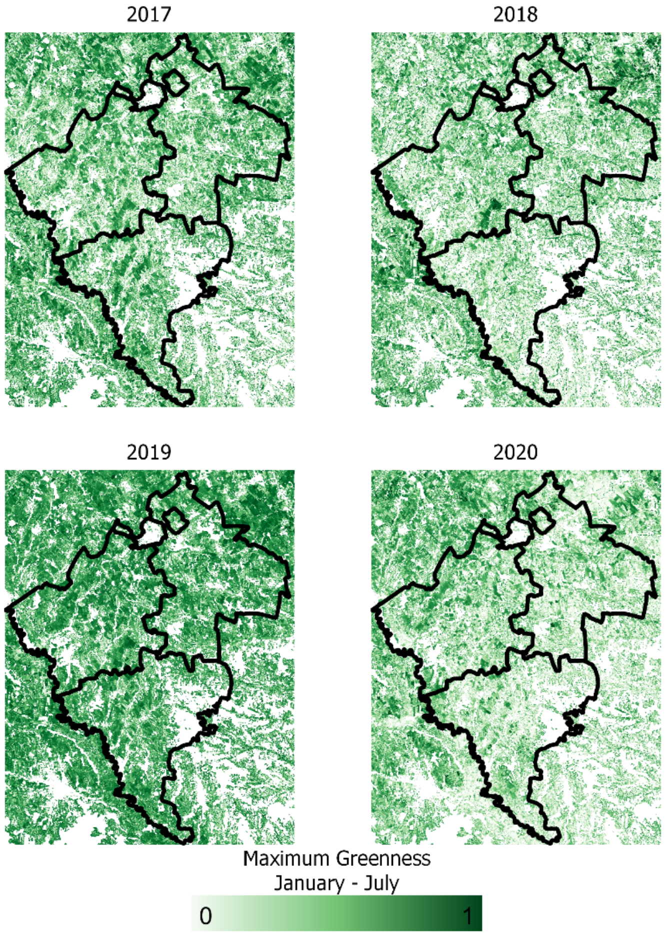




Service 1: 2020 results

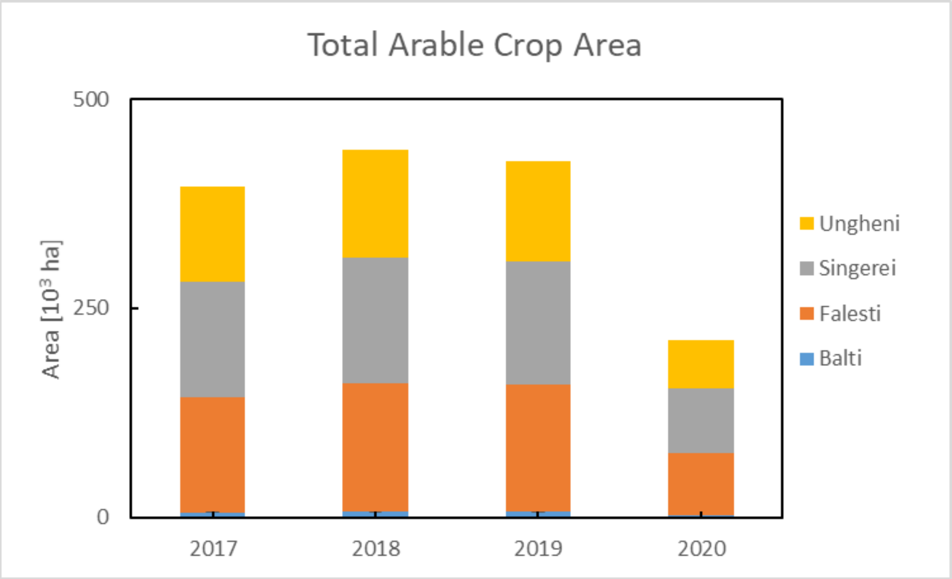
- Maximum Greenness differences of 2020 compared to previous years less evident if considering only the period January - July

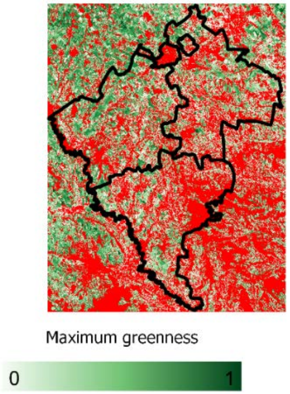




Service 1: 2020 results

- Amount of arable crop area less influenced by short time series considered
- It can be the result of different factors: crop rotation, management, drought, COVID





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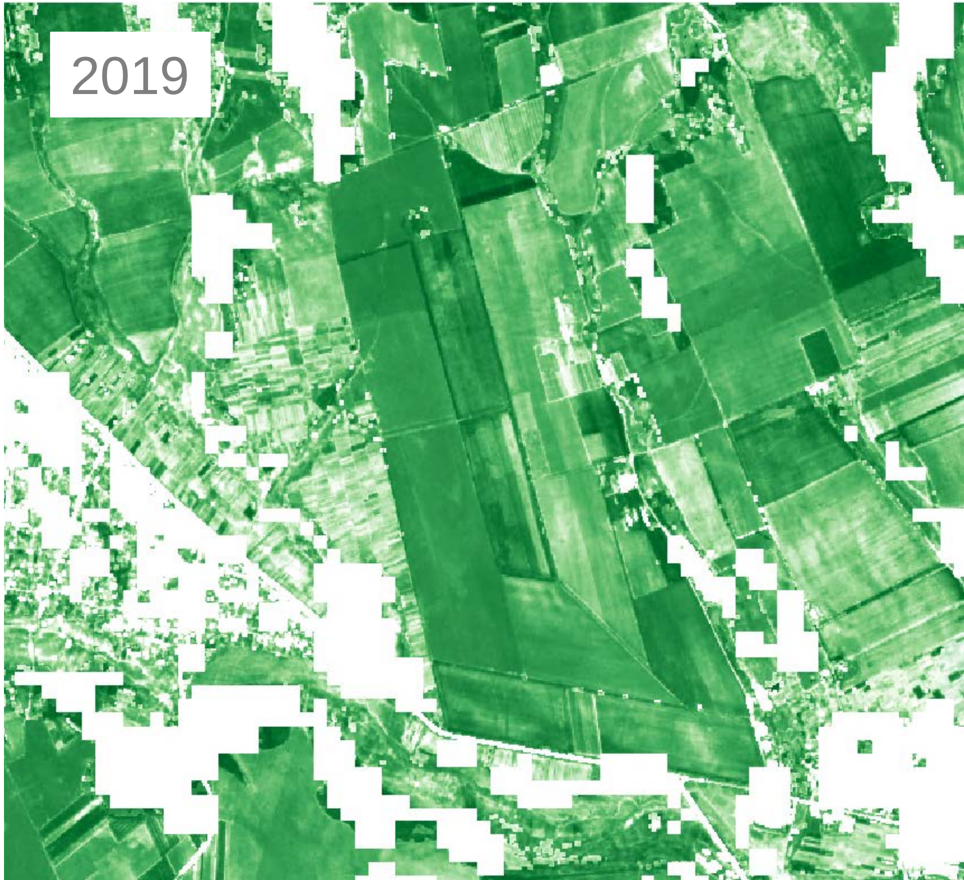
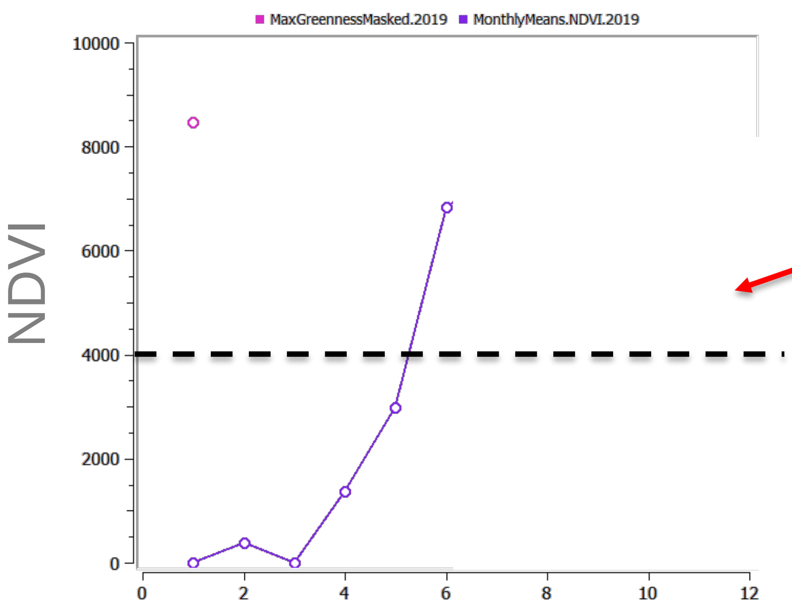


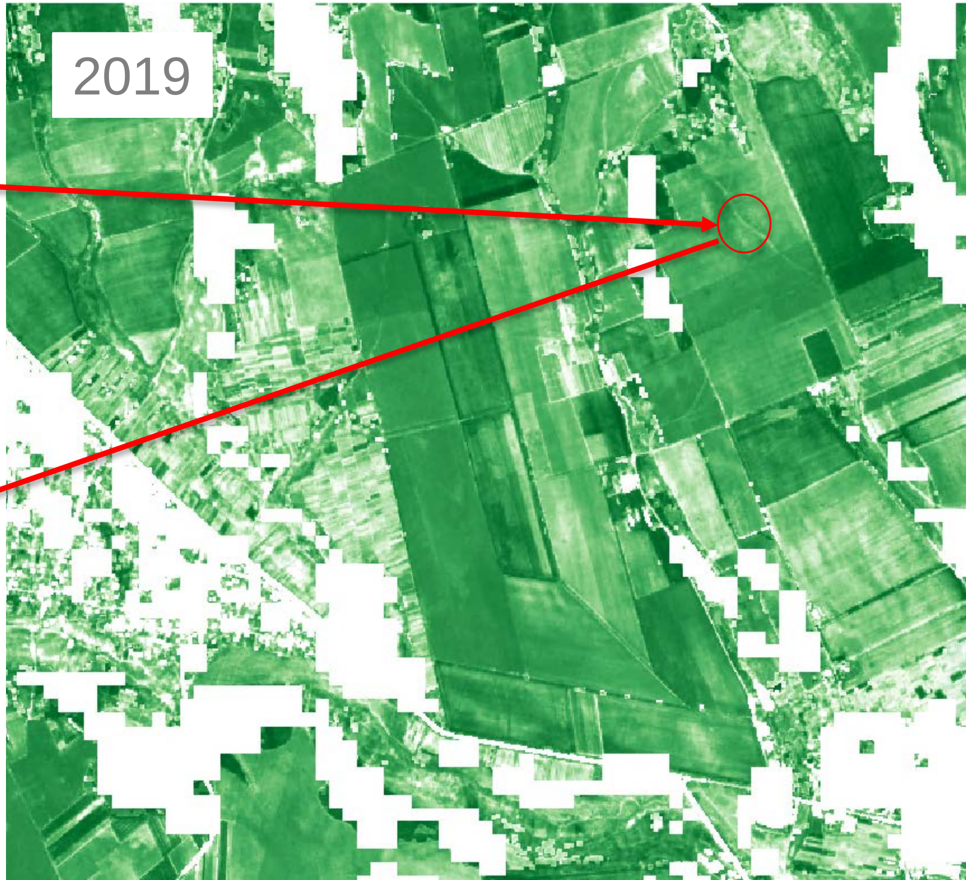
Service 1: 2020 results

- Amount of arable crop area less influenced by short time series considered
- It can be the result of different factors: crop rotation, management, drought, COVID
- Example over 2 types of unhealthy crops

Service 1: 2020 results

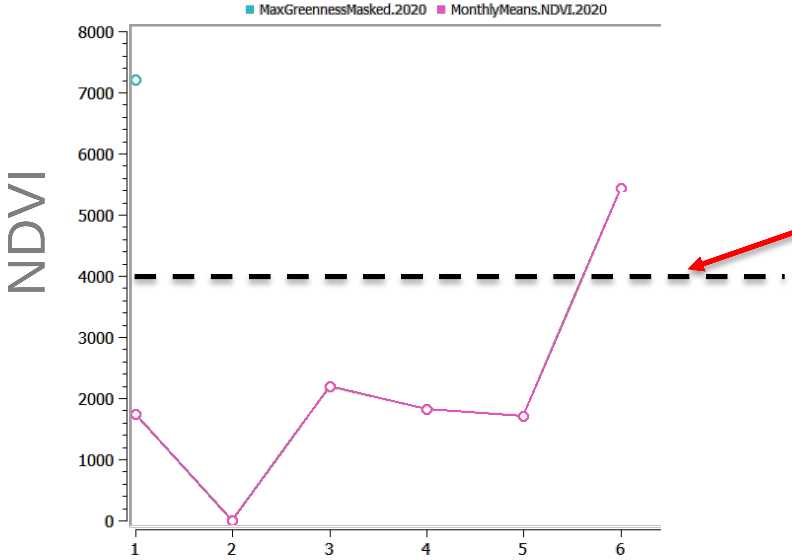
- 2019 Healthy crops show evidence of rapid growth





Service 1: 2020 results

- Similar trend in 2020. Reduced greenness possibly due to short time series and drought



Service 1: 2020 results

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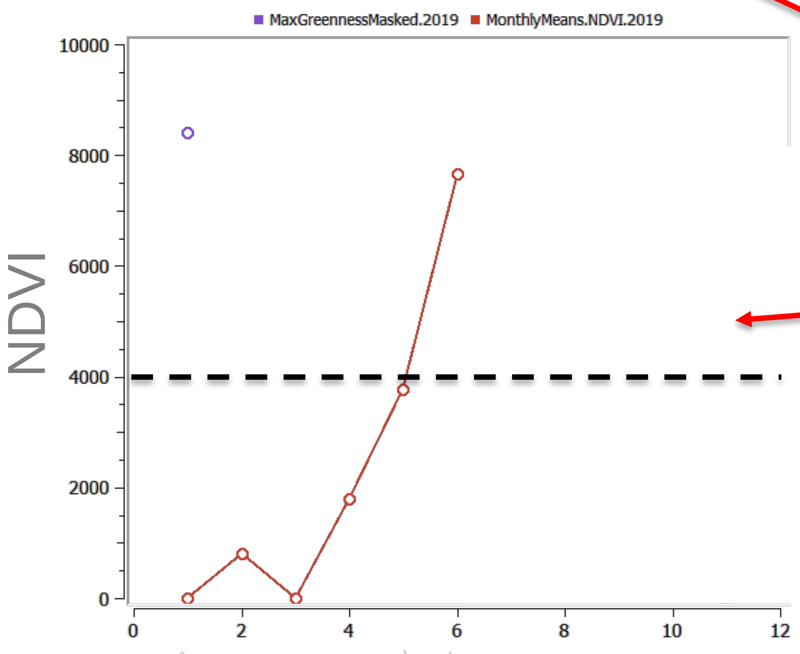
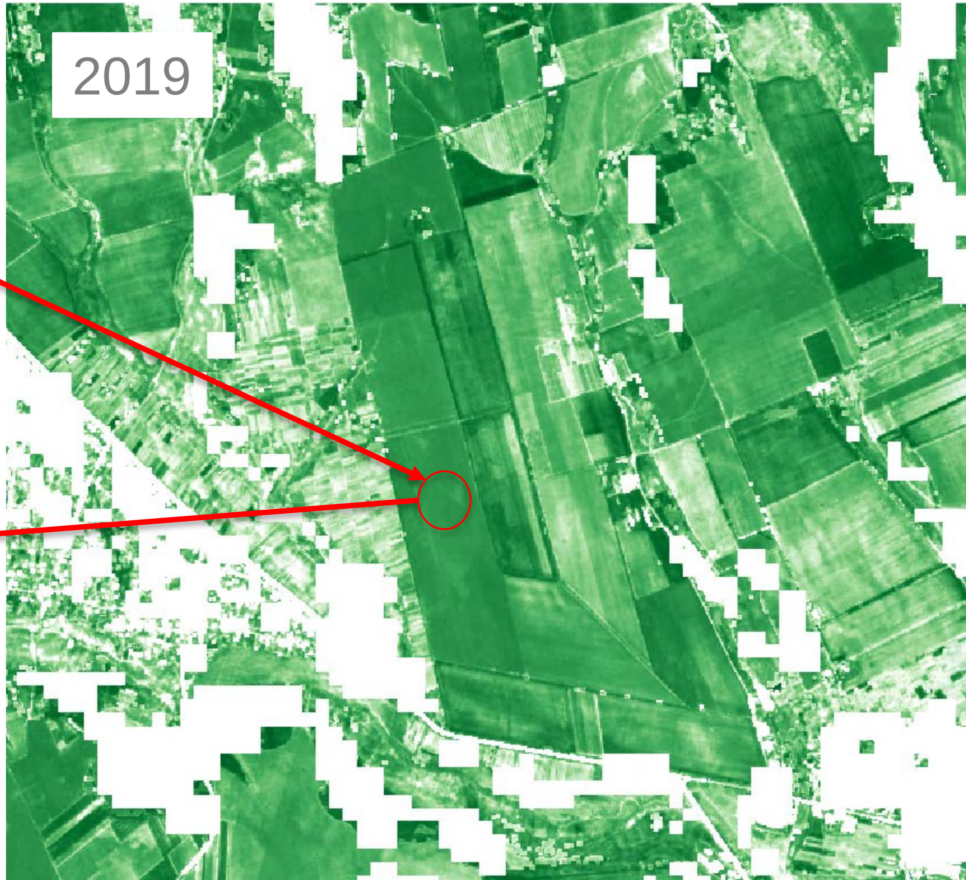
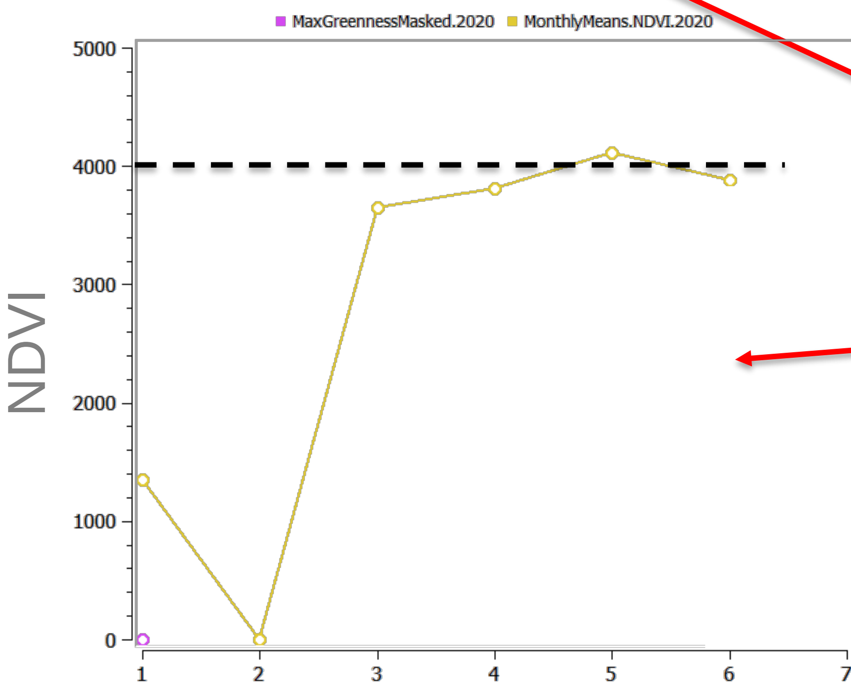
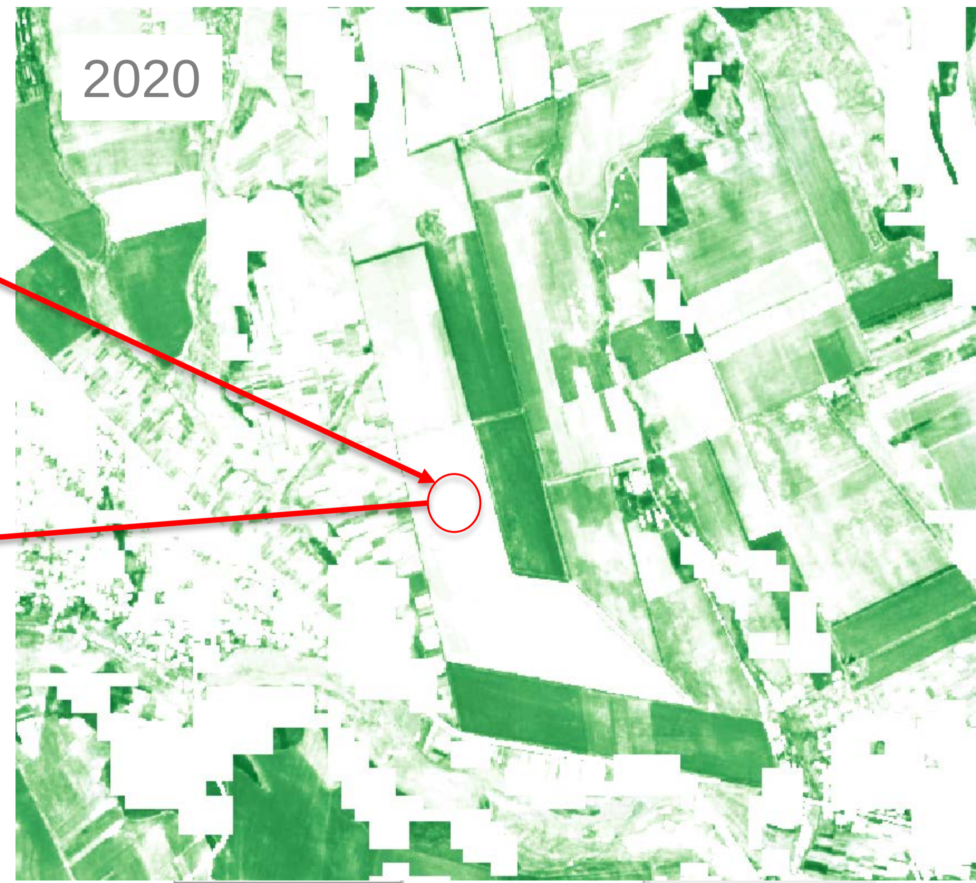




Service 1: 2020 results

- Not sown / dead crop. Not counted as 2020 arable land





Service 1: Possible improvements

- Extend the area of interest to the full country
- Extend the 2020 analysis up to October / November
  - Improved Max Greenness and total arable crop estimation
  - Improved season characterization
  - Enables temporal quality checks
  - Enables harvesting evidence layer
- Include reference data.
  - Ancillary crop type dataset required for crop stratification
  - Crop differentiation enable spatial explicit anomaly maps
  - Enables validation of output products

SERVICE 2
Mobility Trends to Reveal Agricultural Practice Anomalies

Analysis and evaluation of status of **orchards** in 2020 season and detection of anomalies in **mobility trends**. Spatial integration between vegetation deviations (crops and orchard) and mobility anomalies to detect areas affected by changes in workforce movements due to Covid-19 outbreak.

As **mobility data are not available** the analysis has been focused on the integration of vegetation deviations with the spatio – temporal evolution of 112-emergency calls for suspicious Covid-19 cases.

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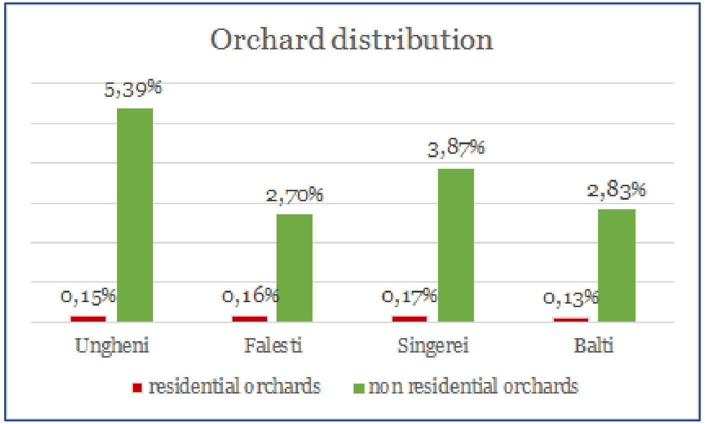
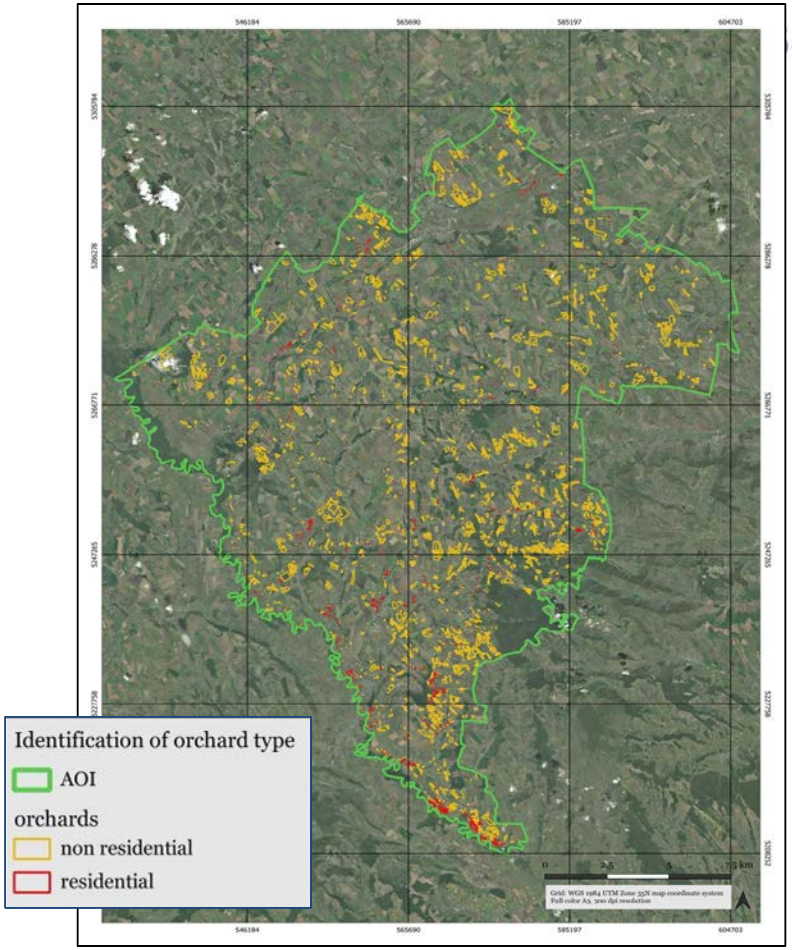
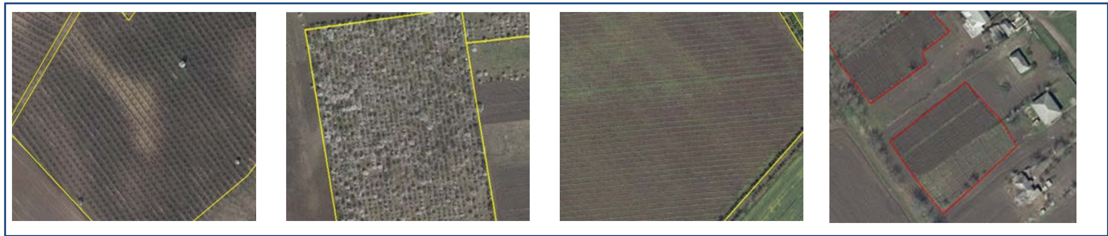
MAPPING ORCHARD DISTRIBUTION

Orchards mapping has been derived from 2016 orthoimagery by means of visual interpretation. Orchard refers to cultivated trees and/or small - medium shrubs, spatially well distributed in distinct blocks. The orchards have been divided into residential and non residential.







ORCHARD CHARACTERIZATION (2017 – 2020 growing seasons)

For each season, phenological parameters have been mapped at pixel level (that is, at the original spatial resolution of Sentinel-2 imagery, 10 m) and further summarized for each orchard field in the AOI. Mapped parameters are: **Start** and **Mid of the Season** and seasonal **Length**, **Amplitude** and **Small Integral**.

MAIN PURPOSE

- Orchard characterization during growing season
- Identification of the key development stages for orchard areas (considering the temporal dynamic of these parameters in the 2017-2020 time-series)

ORCHARD CHARACTERIZATION – Adopted approach

INPUT DATA

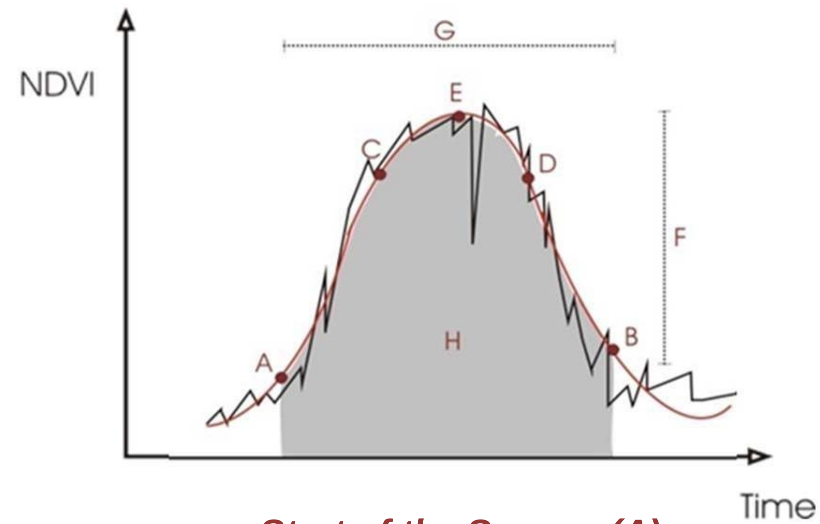
Sentinel-2 BOA reflectance imagery

Monthly NDVI time-series generation
Jan, 2017 – May, 2020

For the ongoing season, estimate of monthly NDVI values from May, 2020 to the end of the season

TIME-SERIES MODELLING

1. Residual outliers removal (noise reduction) from time-series and gap filling (cloud effect reduction)
2. Local fitting of yearly NDVI function (to asymmetric Gaussian function)
3. Extraction of phenological parameters for each season in the time-series



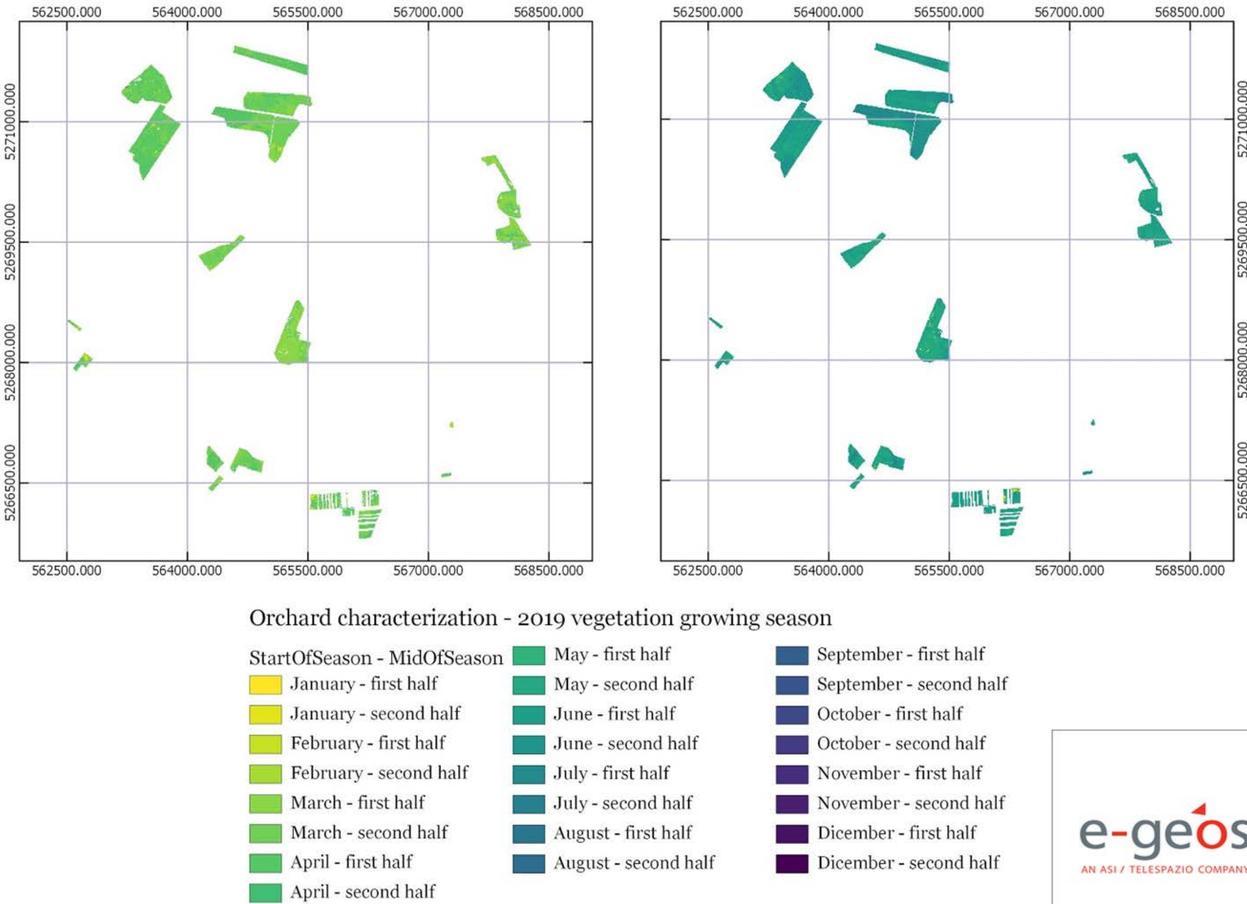
Start of the Season (A)

Mid of the Season (E)

Season Length (G), Season Amplitude (F)

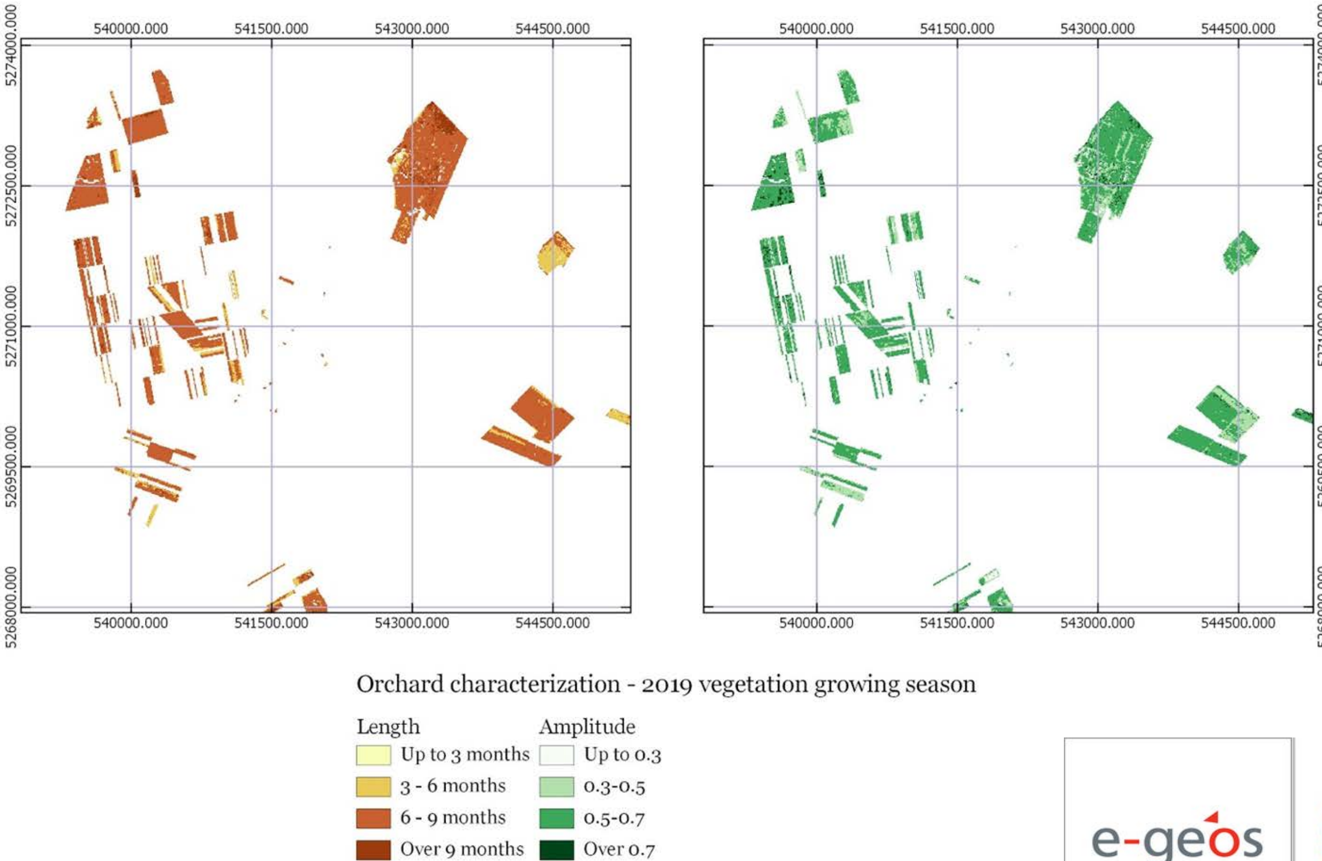
Seasonal Integral (H)

ORCHARD CHARACTERIZATION (2017 – 2020 growing seasons)



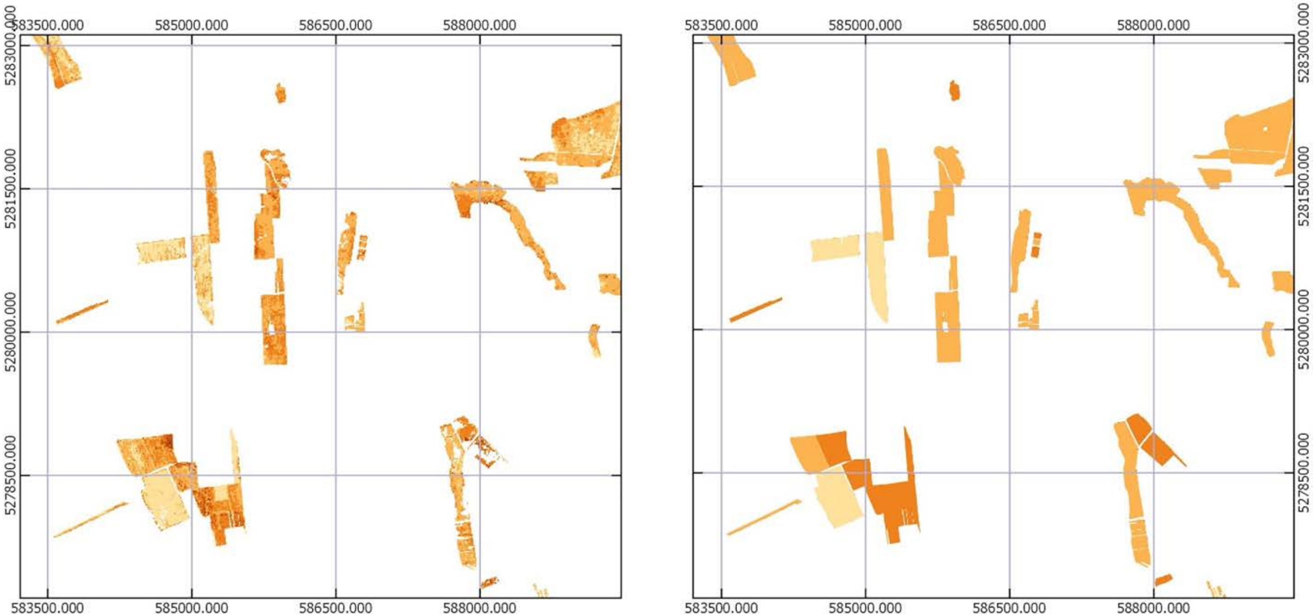
Examples of Start Of Season (left image) and Mid Of Season (right image) phenological parameter maps produced at pixel level (only orchard areas are represented in map) for the 2019 vegetation growing season.

ORCHARD CHARACTERIZATION (2017 – 2020 growing seasons)



Examples of seasonal Amplitude (right image) and Length (left image) maps produced at pixel level (only orchard areas are represented in map) for the 2019 growing season. Orchard areas and natural vegetated areas generally show longer seasonal photosynthetic activity (generally 6-9 months) respect to crop areas and comparable NDVI dynamic, or amplitude.

ORCHARD CHARACTERIZATION (2017 – 2020 growing seasons)



Orchard characterization - 2019 vegetation growing season

SeasonalSmallIntegral_2019

- <= 10000
- 10000 - 20000
- 20000 - 30000
- 30000 - 40000
- 40000 - 60000
- > 60000

Example of map of the of Seasonal Small Integral (SMI) parameter produced at pixel level (left image, outputs are produced in raster format) and at orchard level (right image, outputs are polygon vectors with statistic metrics) for the 2019 growing season. This parameter is particularly relevant, since it is able to describe synthetically the trend of the season in both the time and the NDVI domains and it proves, in literature, to be generally well correlated with the seasonal vegetation health and productivity.

MAPPING OF 2020 ORCHARD STATUS

For the **Start of Season** and the **Seasonal Small Integral** phenological parameters, positive and negative deviations observed in the 2020 growing season respect to the reference behaviour (2017-2019 average value) have been mapped at pixel level. Deviations have been also evaluated and mapped at orchard level selecting a proper classification schema and considering a maximum frequency approach.

MAIN PURPOSE

Detection of orchard areas affected by modified conditions in the 2020 vegetation growing season, that is, with caution, areas where fruit tree evolution is different from previous years

Furthermore, starting from provided phenological parameter maps describing each season in the 2017-2020 time interval, user is able to produce local customized deviation maps in a proper GIS environment. For instance, considering the deviation respect to a particular year in the time-series, according to the local observation of the vegetation cycles in the specific area.

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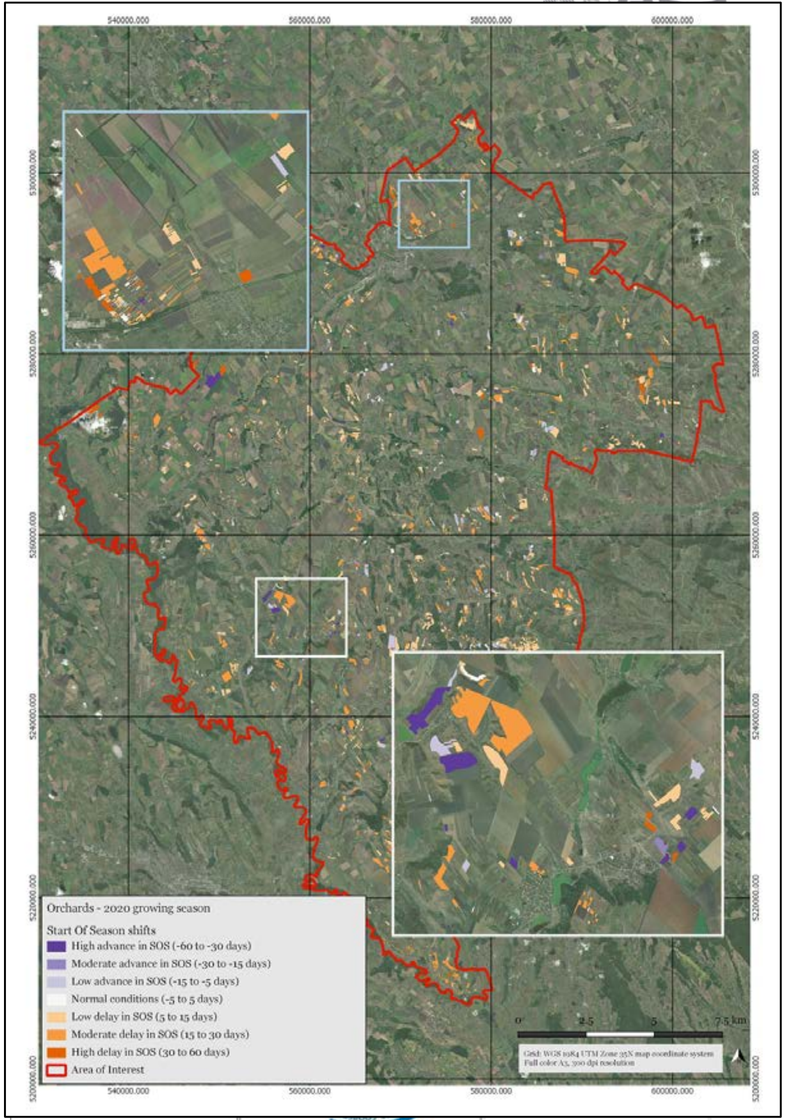
MAPPING OF 2020 ORCHARD STATUS

Map of Start of Season shifts

Deviations in the Start of the Season parameter have to be interpreted in terms of possible advances or delays in the start of the photosynthetic activity (as registered in satellite observations and modelled using proposed methodology) for the 2020 growing season respect to previous years



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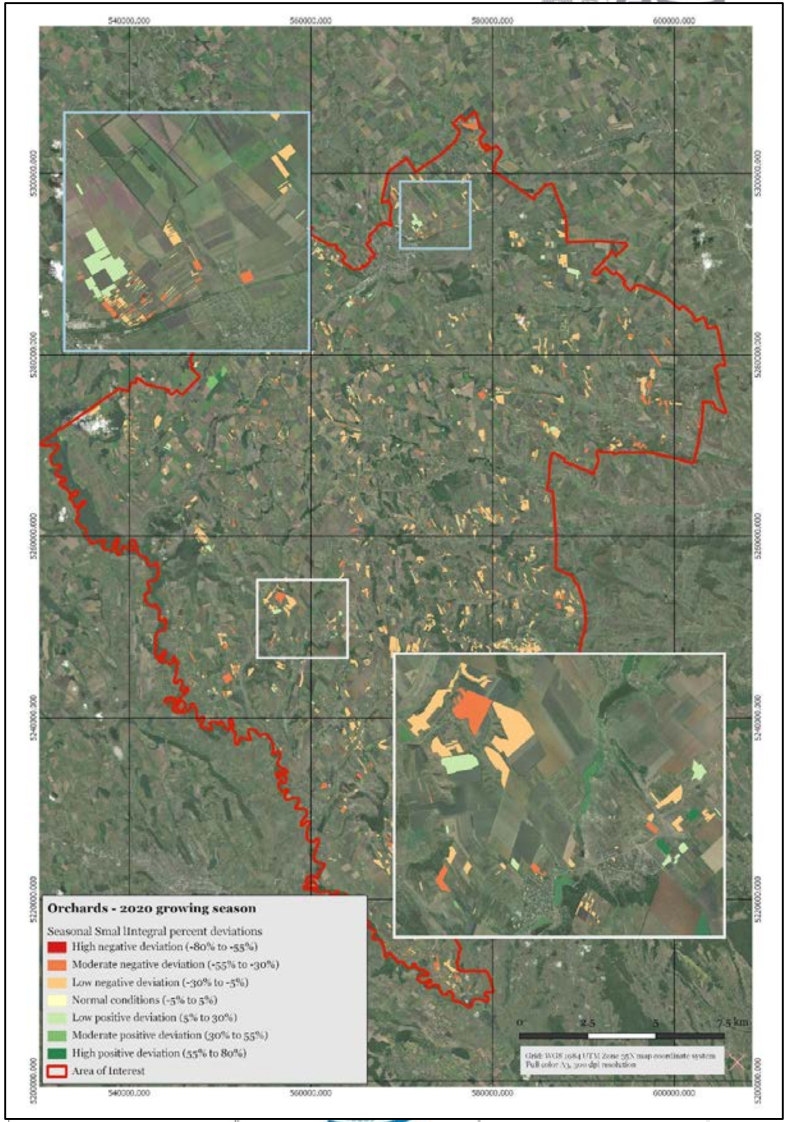
MAPPING OF 2020 ORCHARD STATUS

*Map of **deviations in orchard plant health***
(Seasonal Small Integral percent deviations)

Negative deviations may help to identify orchard areas where reduction in vegetation greenness and biomass are expected for the 2020 growing season respect to previous years, according to the NDVI temporal evolution modeled starting from available Sentinel-2 imagery (up to May 2020)



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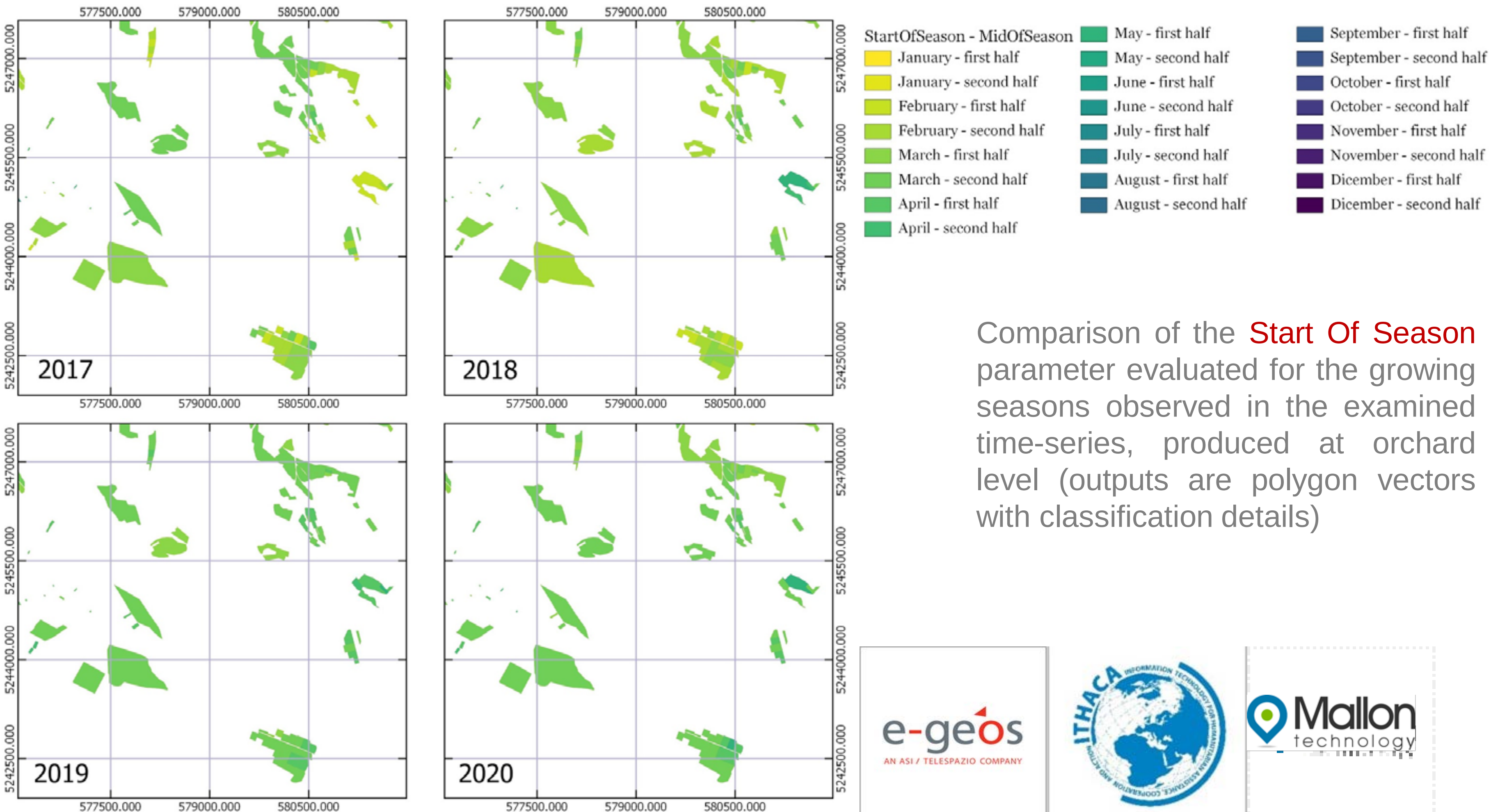
MAPPING OF 2020 ORCHARD STATUS



Comparison of the Start Of Season parameter evaluated for the growing seasons observed in the examined time-series, produced at orchard level (outputs are polygon vectors with classification details)

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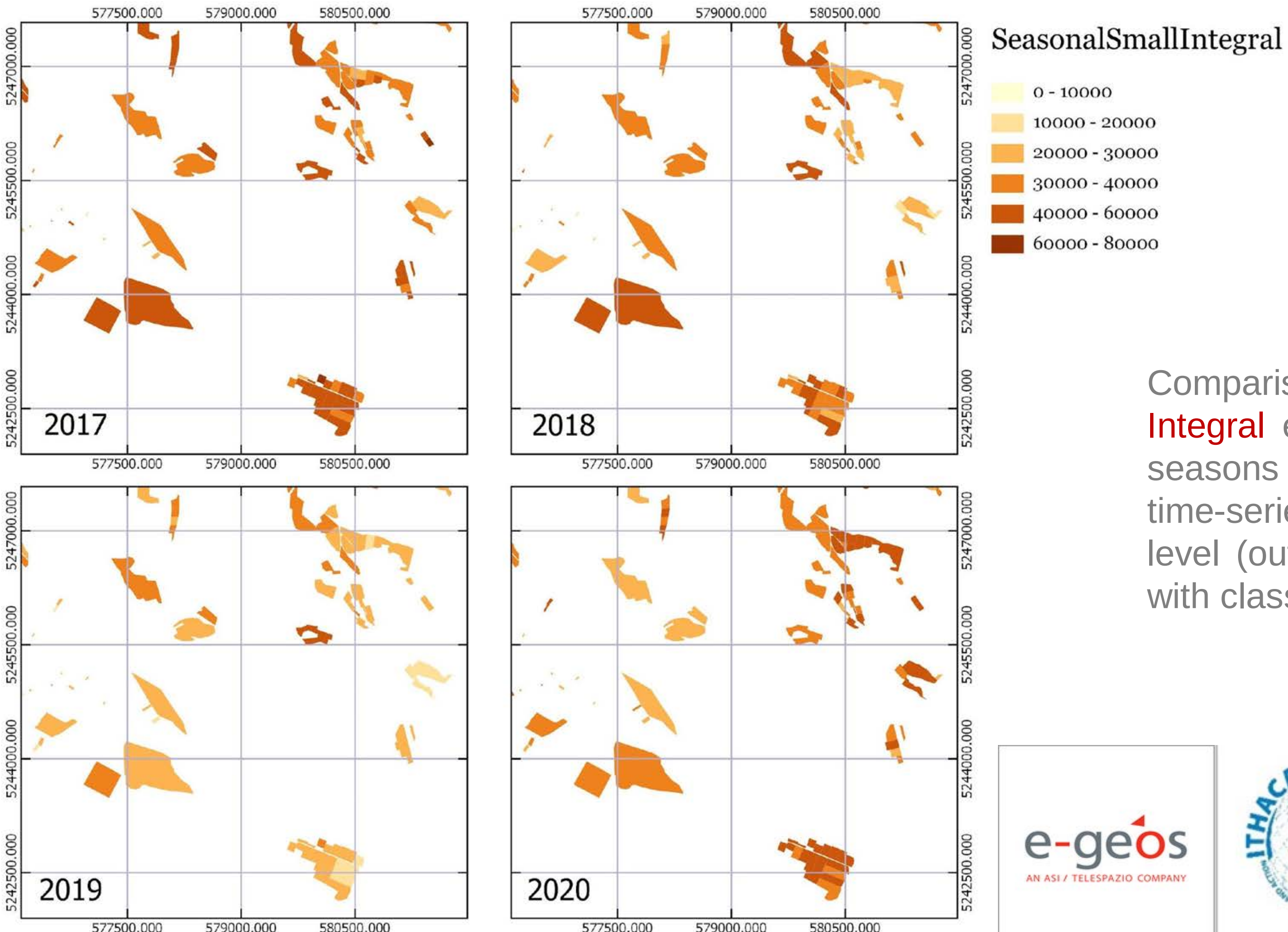
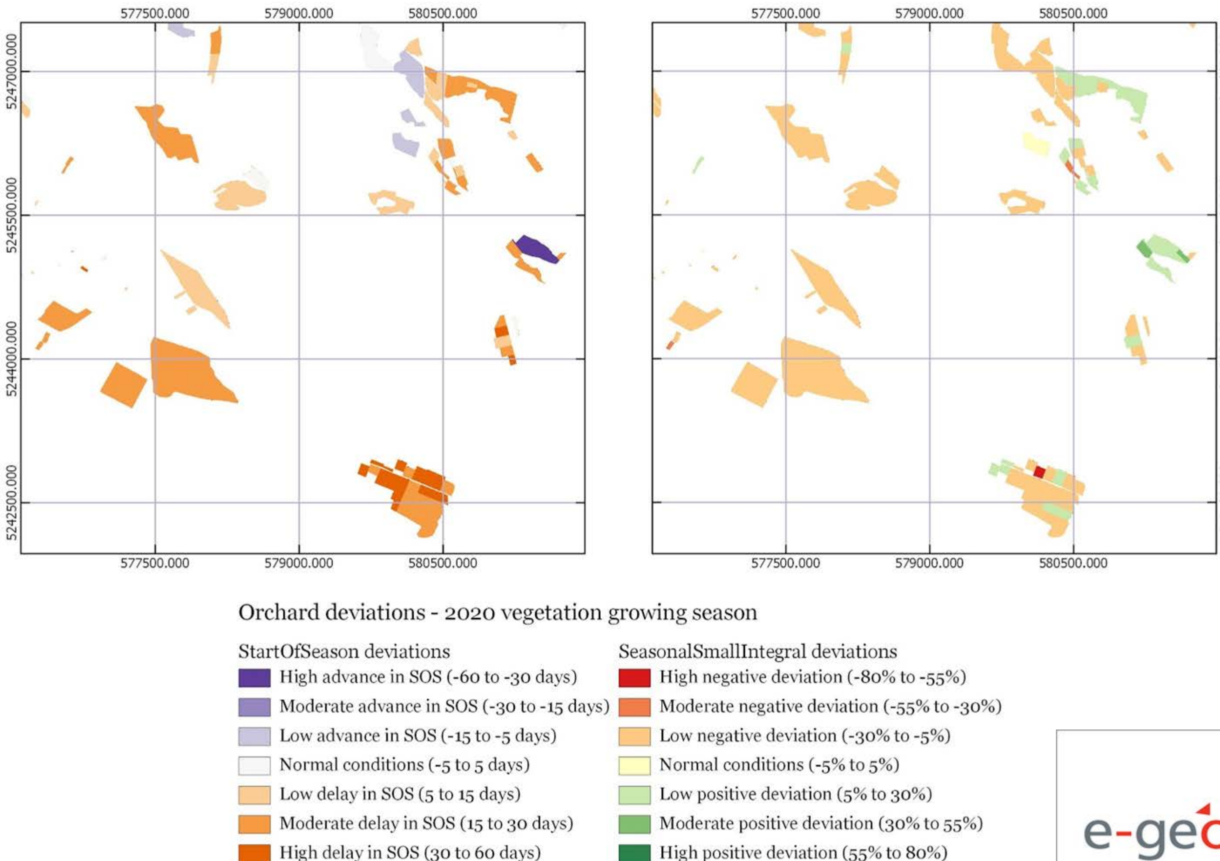
MAPPING OF 2020 ORCHARD STATUS



Comparison of the Seasonal Small Integral evaluated for the growing seasons observed in the examined time-series, produced at orchard level (outputs are polygon vectors with classification details)

MAPPING OF 2020 ORCHARD STATUS



Examples of maps showing the classes of deviation for the Start Of Season shifts (on the left) and of the percent deviations of the Seasonal Small Integral (on the right) evaluated for the 2020 growing season, produced at orchard level (outputs are polygon vectors with classification details)

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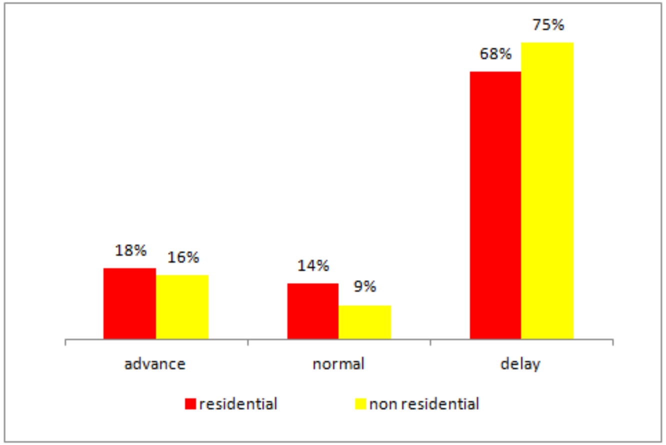
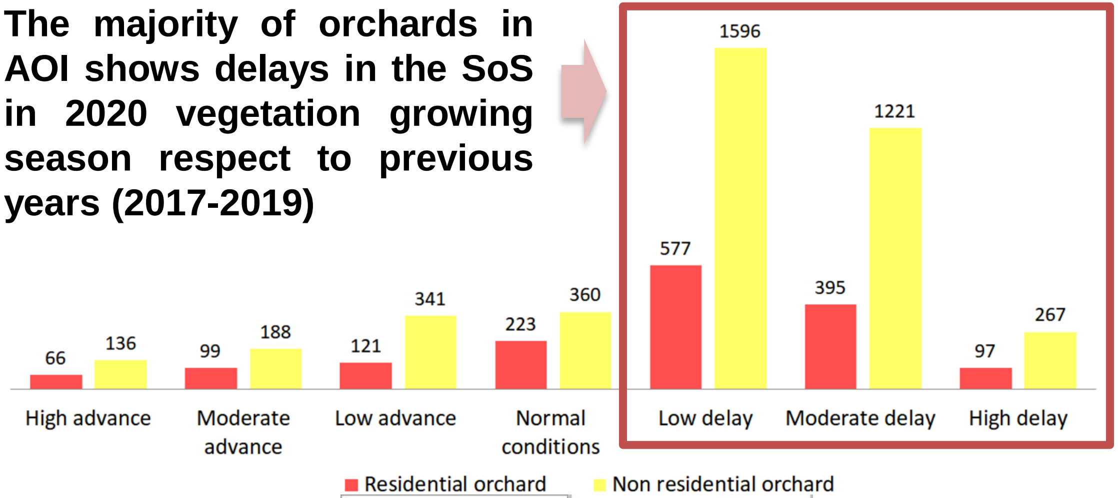
MAPPING OF 2020 ORCHARD STATUS

Distribution of deviations in the start of photosynthetic activity (as registered in satellite observations) of orchard plants in AOI (Start Of Season shifts) for the 2020 growing season respect to 2017-2019, considering the 2020 vegetation season in the period January to May - *number of orchards/percentage of orchards.*

Observed delays in the SOS are slightly more frequent in orchard fields located in non residential areas



The majority of orchards in AOI shows delays in the SoS in 2020 vegetation growing season respect to previous years (2017-2019)



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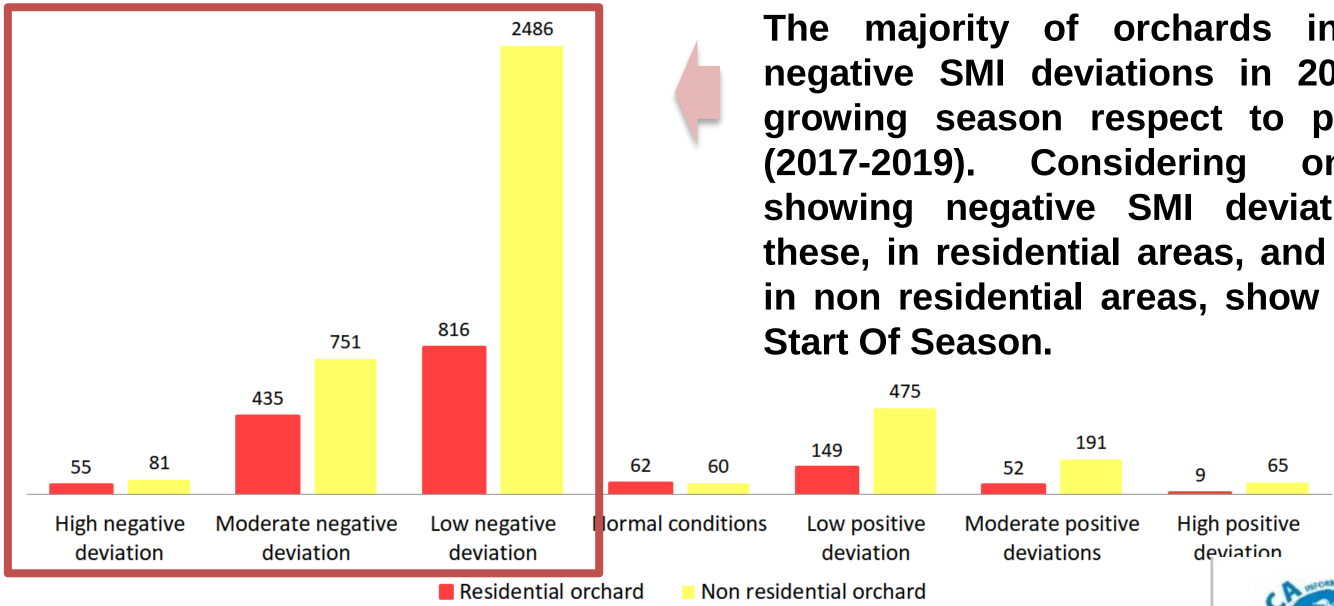
MAPPING OF 2020 ORCHARD STATUS

Distribution of deviations in observed orchard plant health in AOI (Seasonal Small Integral percent deviations) for the 2020 growing season respect to 2017-2019, considering the 2020 vegetation season in the period January to May - *number of orchards.*



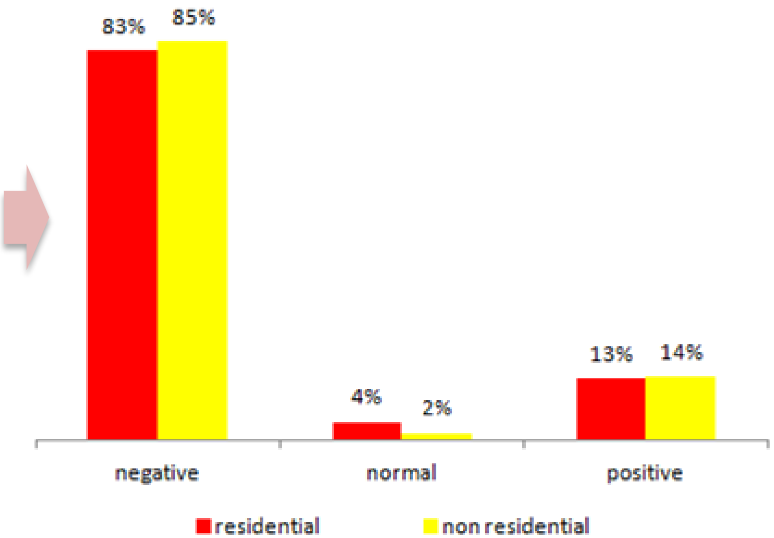
The majority of orchards in AOI shows negative SMI deviations in 2020 vegetation growing season respect to previous years (2017-2019). Considering only orchards showing negative SMI deviations, 72% of these, in residential areas, and 78% of these, in non residential areas, show a delay in the Start Of Season.

MAPPING OF 2020 ORCHARD STATUS

Distribution of deviations in observed orchard plant health in AOI (Seasonal Small Integral percent deviations) for the 2020 growing season respect to 2017-2019, considering the 2020 vegetation season in the period January to May - *percentage of orchards.*

In case the logistics limitation in spring 2020 due to the Covid and lockdown was the only negative factor impacting the orchard status, we would expect less negative deviations in residential orchards, while the proportion of negative and positive deviations related to vegetation health condition seems to be similar both in residential and in non residential orchards. Therefore, probably other factors (e.g. agro-meteorological ones) affected in a greater measure the orchard vegetation conditions observed in the present year, or the effects of Covid in first months of the year could be evident only later during the season. An analysis performed at the end of the season would estimate more effectively the distribution of the deviations.**

*** Assuming that residential orchards are mostly located in residences where people passed the lockdown period*



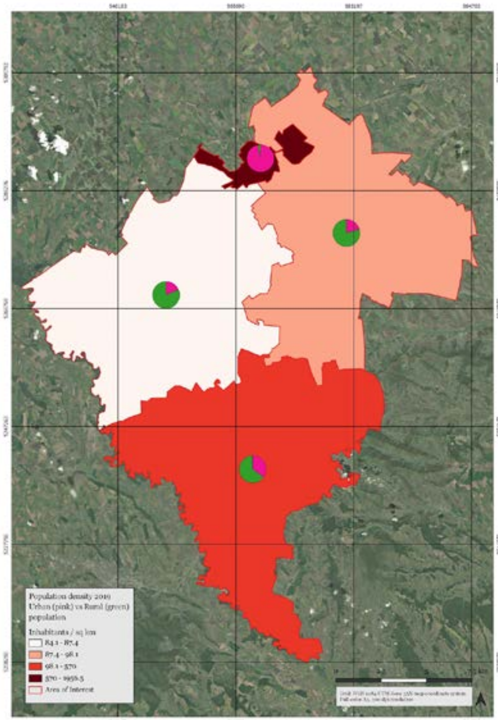
LIMITATIONS

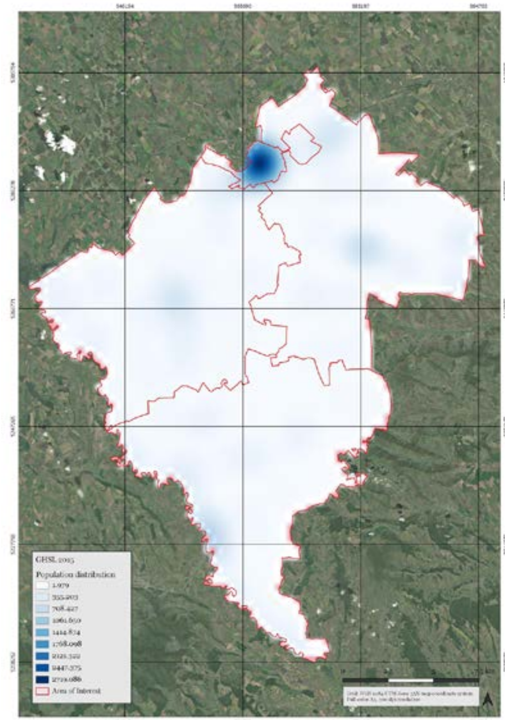
- The presence of tree plantation and reforestation areas whose regular pattern is often confusing with orchard one in some cases limits the orchard field mapping in the AOI
- Phenological parameters for the 2020 growing season are extracted from an estimate of the seasonal NDVI function (season still ongoing at the time of the analysis)
- Phenological parameters are extracted from satellite-derived vegetation indexes and through a modelling process
- Cloud coverage affecting satellite optical acquisitions limits the temporal and spatial completeness of used NDVI time-series
- The proposed methodology does not allow to identify the actual causes of observed deviations, which could be also related to different climatic conditions in the observed years or land cover changes. These latter have not been considered in the proposed methodology and the orchard map derived from 2016 orthoimagery has been used

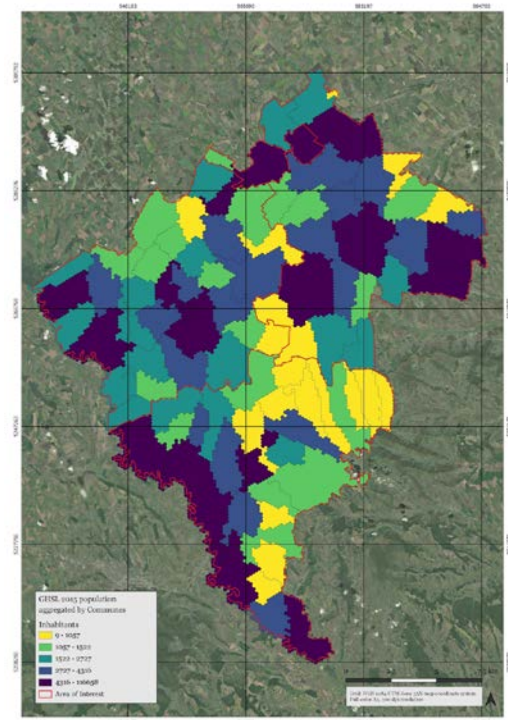
IMPROVEMENTS

- According to the update of available orthoimagery, the possibility to identify stable orchard area in the considered years, to be used for vegetation deviation analysis purposes, may be investigated
- The exploitation of recent Sentinel-2 imagery (up to September 2020 or later) in order to expand or complete the NDVI time-series used for the orchard status analysis increases the reliability of calculated phenological parameters describing the 2020 vegetation growing season and their deviation estimates
- The production and mapping of different measures of deviations may help to better describe the current status of vegetation, monitor the growing season and early detect critical conditions that could be related to production anomalies, in the particular case of orchard vegetation. As an example, a SMI Condition Index may be proposed. It compares the current SMI to the range of values observed in previous years. The SMI CI is expressed in % and gives an idea where the observed value is situated between the extreme values (minimum and maximum) in the previous years.
- Furthermore, specific agro-meteo factors could be included in the deviation analyses, in order to better isolate Covid effects on vegetation, particularly due to the lack of ancillary data allowing to perform a specific anomaly analysis of vehicle/people movements related to fruit production logistic. For this purpose, a deep feasibility analysis is required, which takes into consideration base data availability in the AOI and the user expertise that can be involved (i.e. in order to correctly identify the main requirements of plants in the examined areas from an agro-meteo point of view).

DETECTION OF POSSIBLE COVID-19 HOTSPOTS AND THEIR CORRELATION WITH VEGETATION STATUS – POPULATION DATA





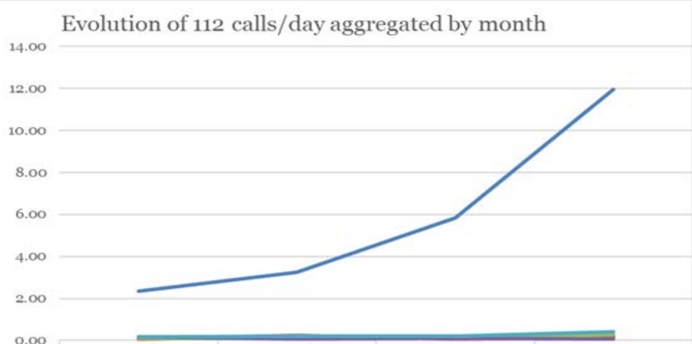


Area	Population 2019 (Statistica Moldovei)	Population 2015 (GHSL)	Percent change 2015 - 2019
Balti	151 791	119 166	21,49%
Falesti	90 275	93 780	-3,88%
Singerei	91 412	90 794	0,68%
Ungheni	116 705	105 038	10,00%
Moldova	3 542 708	3 555 159	-0,35%

DETECTION OF POSSIBLE COVID-19 HOTSPOTS AND THEIR CORRELATION WITH VEGETATION STATUS – 112 EMERGENCY CALLS

INPUT DATA provided

- 112-emergency calls, related to Covid-19 suspicious cases:
  - Spatial coverage: whole Moldova
  - Temporal coverage: from 16/03/2020 to 14/06/2020
  - Spatial resolution: hexagonal grid of ~ 26 hectares



	March	April	May	June
Bălţi	2.33	3.24	5.82	11.96
Făleşti	0.07	0.25	0.08	0.18
Sângerei	0.11	0.10	0.11	0.27
Ungheni	0.16	0.08	0.09	0.07
Grand Total	0.16	0.21	0.22	0.42

Admin. division	Confirmed cases	Population 2019	Covid-19 rate	Calls 112	Calls 112 rate	Calls on confirmed cases
Balti	1 401	151 791	0.92%	980	0,65%	69,95%
Falesti	380	90 275	0.42%	450	0,50%	118,42%
Singerei	425	91 412	0.46%	321	0,35%	75,53%
Ungheni	113	116 705	0.10%	269	0,23%	238,05%
Moldova	17 814	3 542 708	0.50%	13 680	0,39%	76,79%

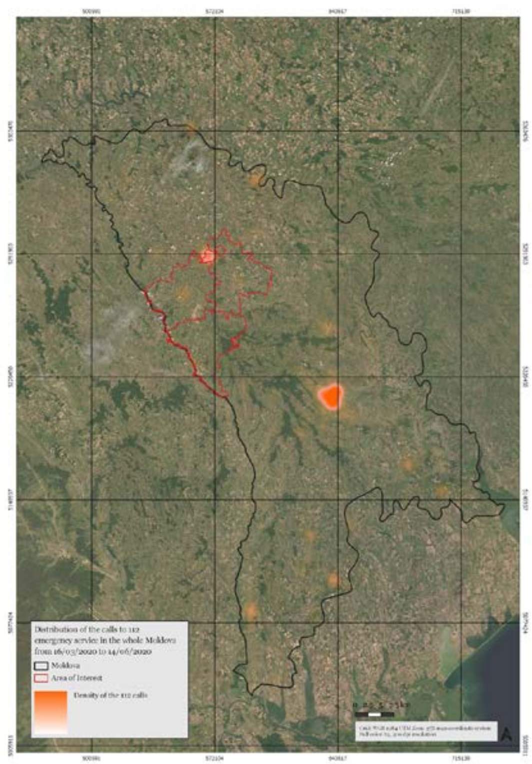
Admin. division	Total Calls	Population GHSL	Average normalised calls on population	Average score of Calls
Balti	960	118 057	1,09	5,00
Falesti	450	95 282	0,73	2,91
Singerei	321	90 612	0,65	2,59
Ungheni	269	110 252	0,61	2,25
Total AOI	**2 000**	**414 203**	**0,67**	**2,64**

LIMITS

- Calls may be not a reliable proxy to describe Covid-19 spreads

DETECTION OF POSSIBLE COVID-19 HOTSPOTS AND THEIR CORRELATION WITH VEGETATION STATUS – 112 EMERGENCY CALLS

Heatmap (kernel density) of the calls aggregated over time window
16/03/2020 to 14/06/2020 (in absolute numbers)



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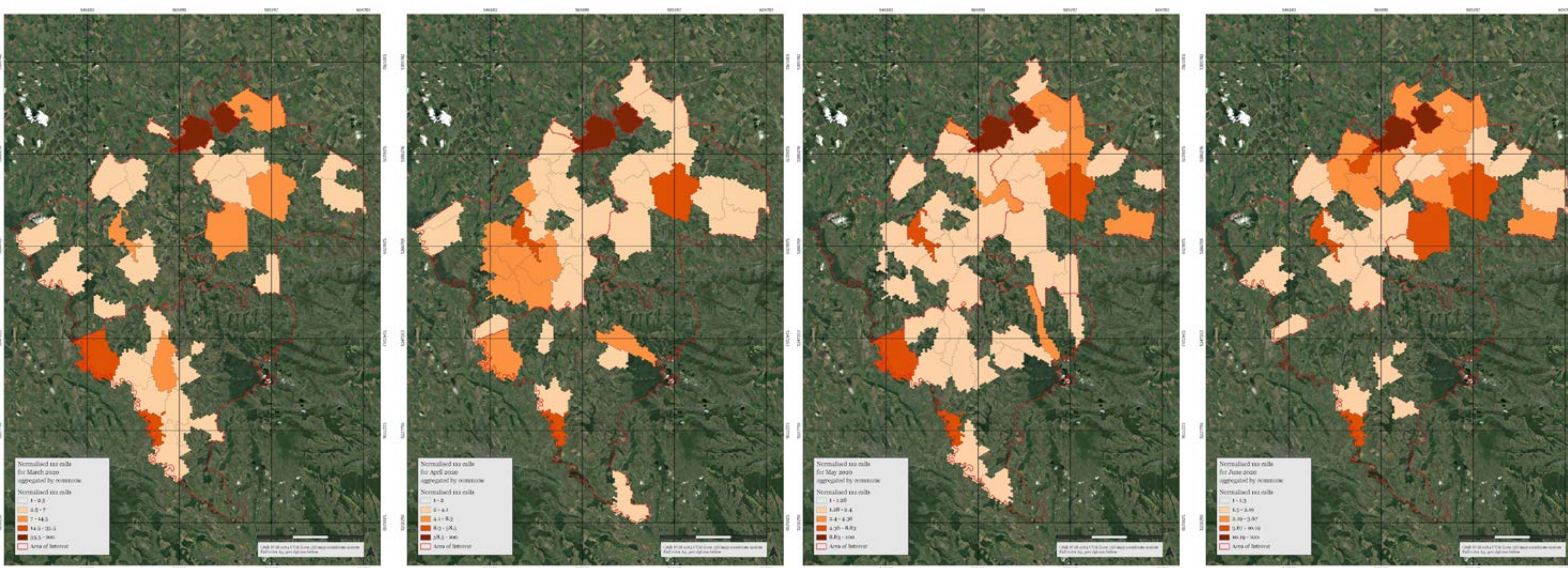
DETECTION OF POSSIBLE COVID-19 HOTSPOTS AND THEIR CORRELATION WITH VEGETATION STATUS – 112 EMERGENCY CALLS

Monthly evolution of the calls aggregated by commune (normalised on population)



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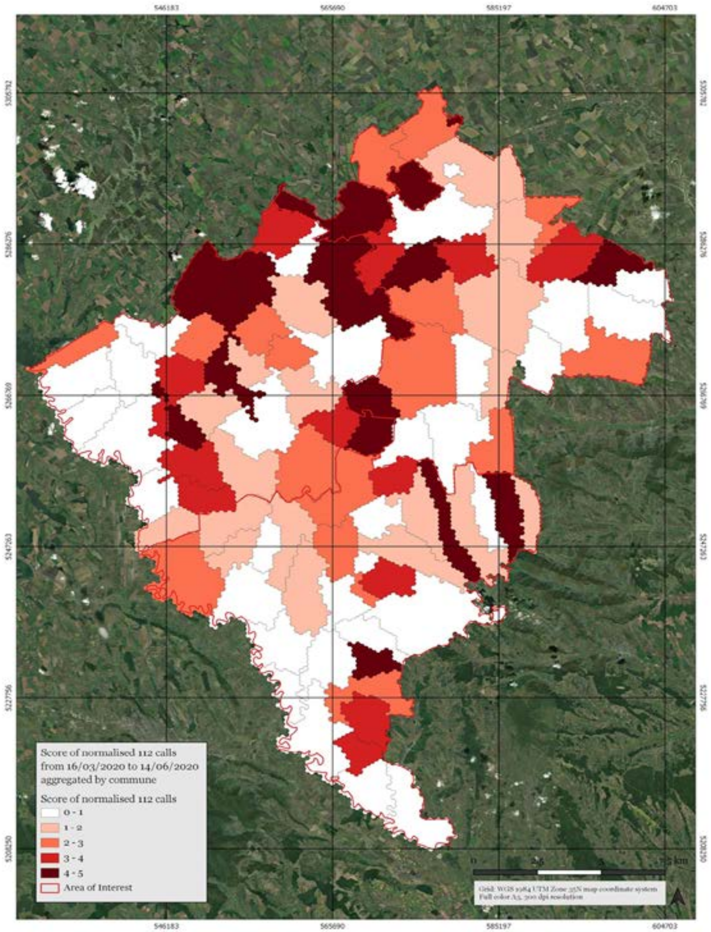
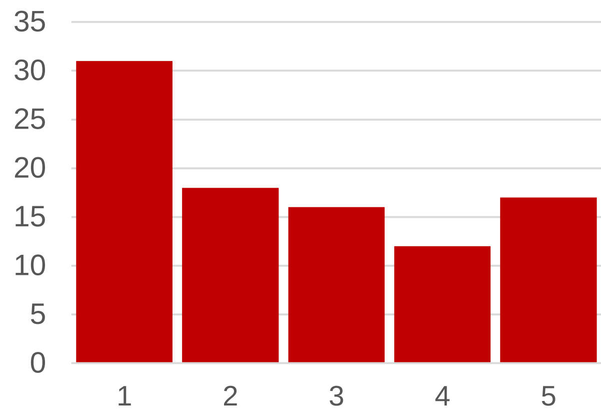
DETECTION OF POSSIBLE COVID-19 HOTSPOTS AND THEIR CORRELATION WITH VEGETATION STATUS – 112 EMERGENCY CALLS



112 emergency calls index

The number of total calls (from March to June) for each commune, have been normalized on population. This values has been then classified in **5 classes**, where high values indicates a high number of calls respect to commune inhabitants.



The chart highlights a general positive situation. Critical values (class 4 and 5) comprises the 30% of communes in the AoI.

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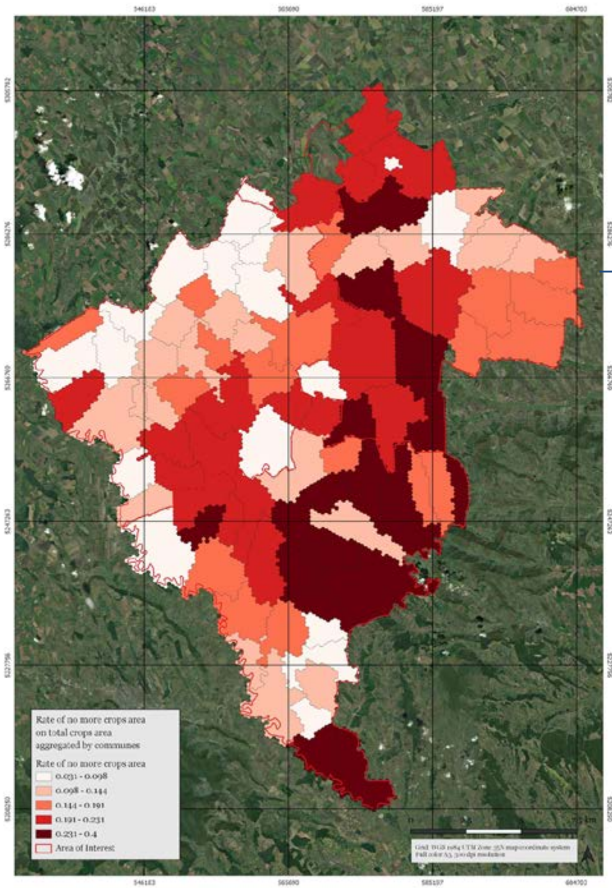
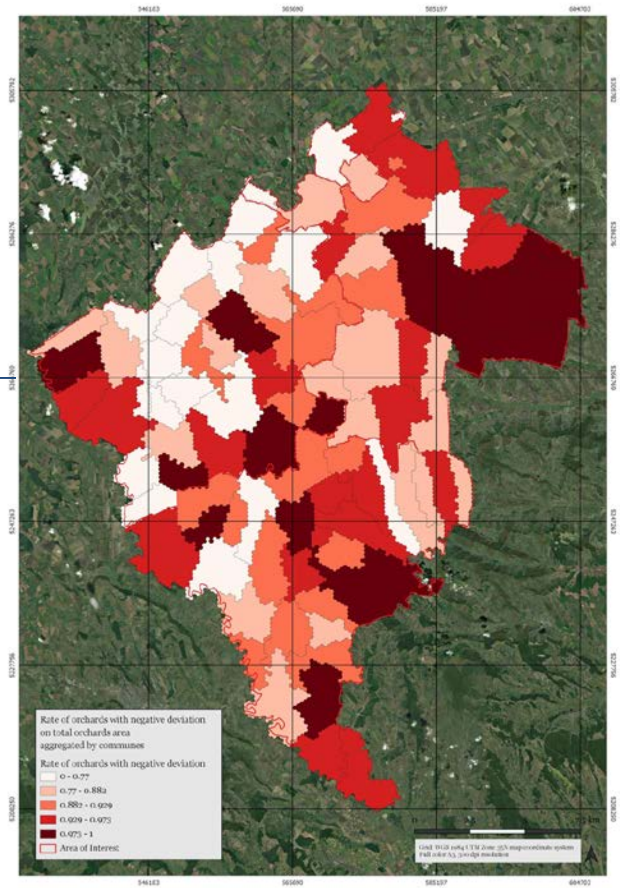
DETECTION OF POSSIBLE COVID-19 HOTSPOTS AND THEIR CORRELATION WITH VEGETATION STATUS – VEGETATION STATUS



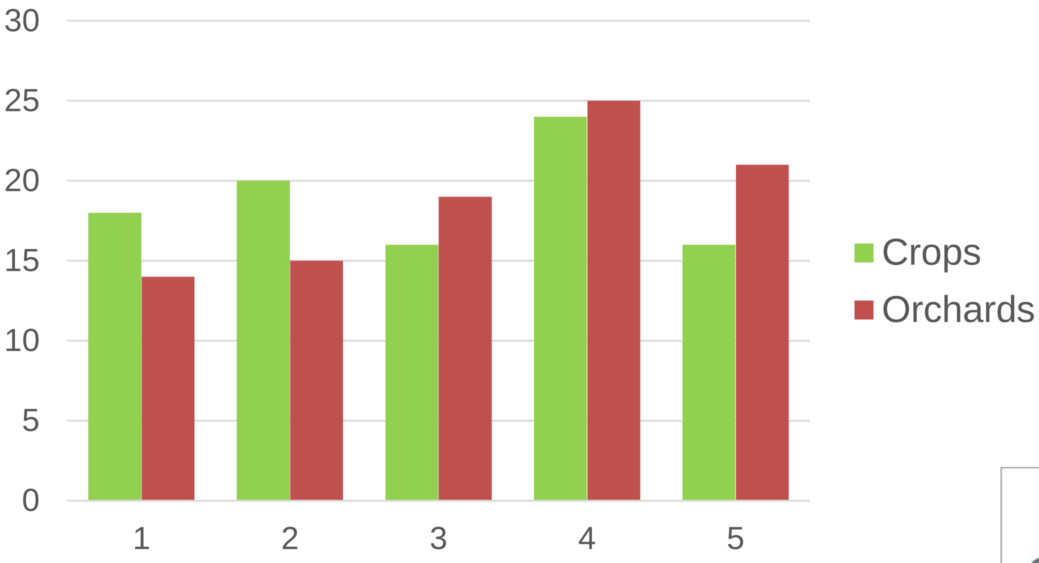
Rate of no more visible crops in 2020 respect to the total crops area in 2019.

Rate of orchards with a negative deviation in phenological parameters in 2020 respect to the total orchards area



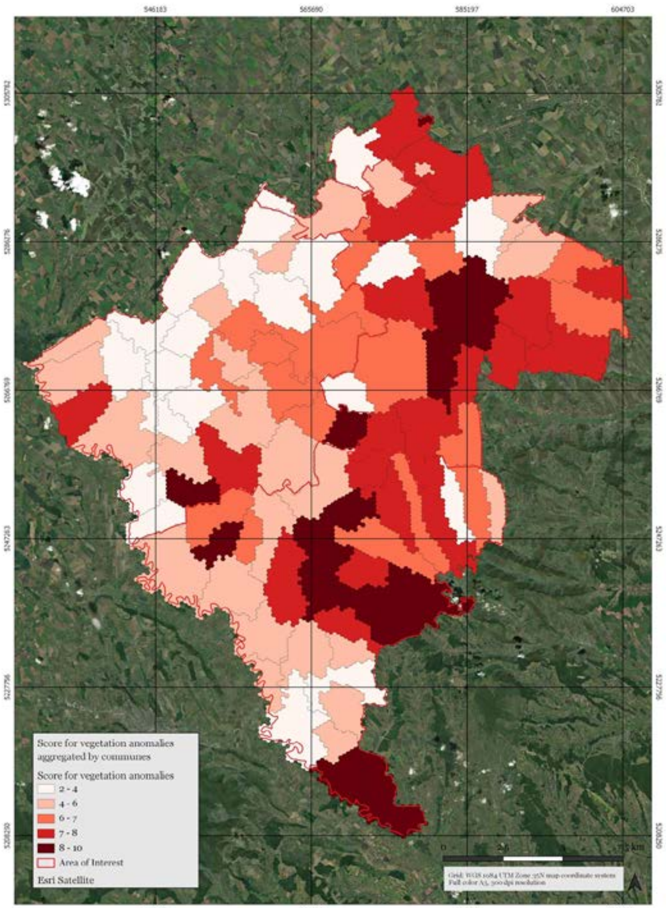
DETECTION OF POSSIBLE COVID-19 HOTSPOTS AND THEIR CORRELATION WITH VEGETATION STATUS – VEGETATION STATUS

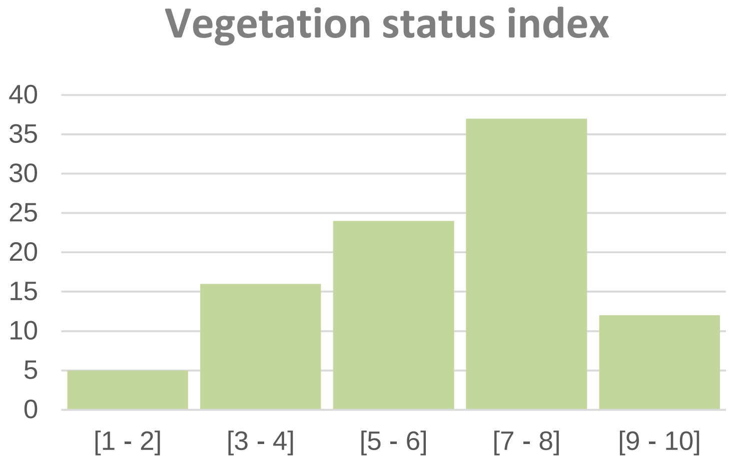
The rate of areas no longer recorded as crops in 2020 compared to 2019, and the rate of orchards with a negative deviation of phenological parameters in 2020 compared to the total area of orchards have been classified in **5 classes**, where high values indicates a negative trend in vegetation status.



The chart compares the vegetational status values reclassified for orchards and crops, aggregated by communes.
Class 4 and 5 contain 42% of communes for crops and 49% of communes for orchards, confirming the negative trend of vegetational status.

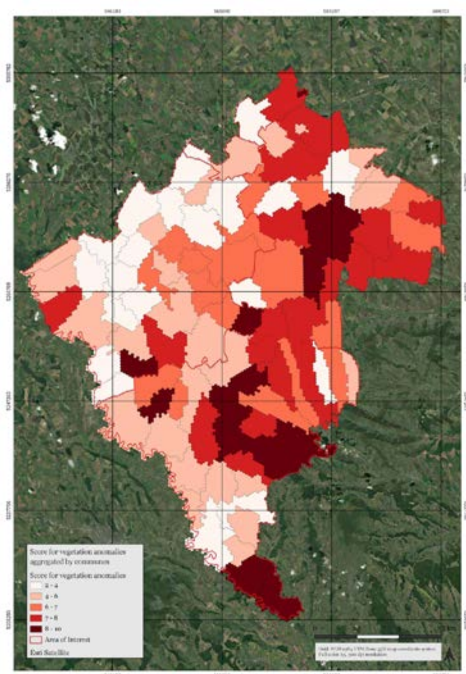
DETECTION OF POSSIBLE COVID-19 HOTSPOTS AND THEIR CORRELATION WITH VEGETATION STATUS – VEGETATION STATUS





The vegetation status index is a summary index given by the sum of crops scores and orchards scores previously described. Also in this case the 52% of communes are classified as critical (classes from 7 to 10).

DETECTION OF POSSIBLE COVID-19 HOTSPOTS AND THEIR CORRELATION WITH VEGETATION STATUS – RESULTS



Vegetation status index

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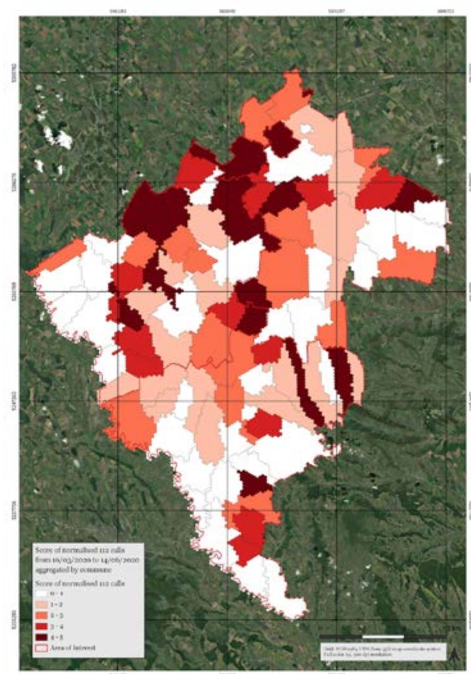

112 emergency calls index

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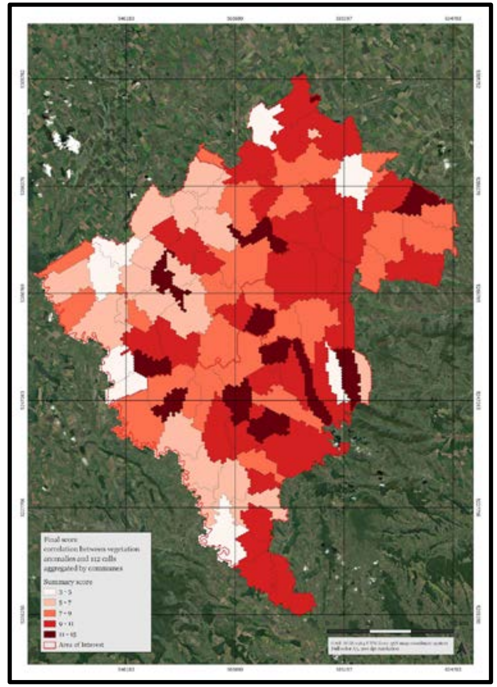
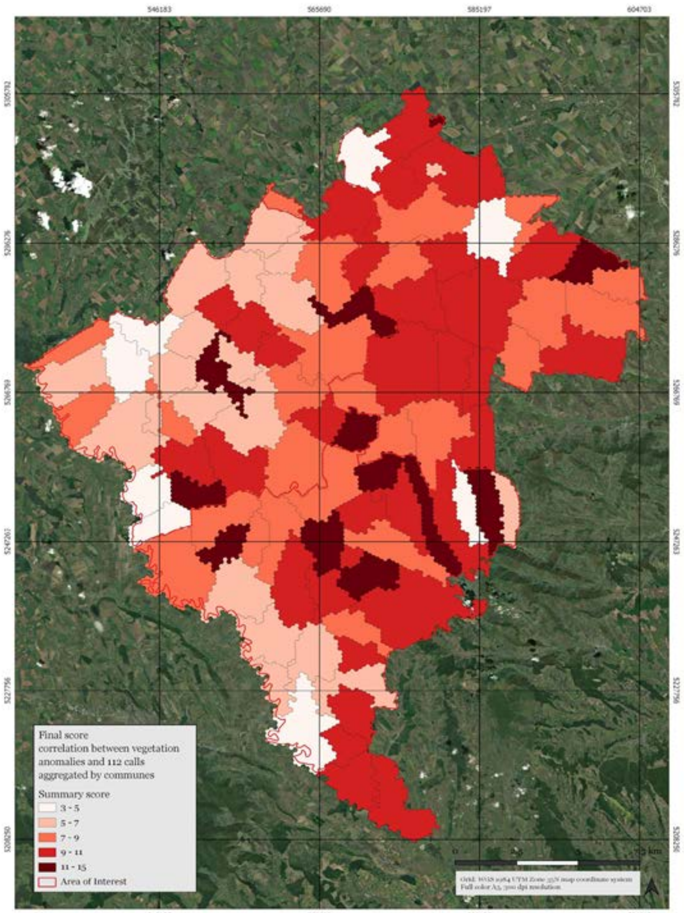
Correlation index



DETECTION OF POSSIBLE COVID-19 HOTSPOTS AND THEIR CORRELATION WITH VEGETATION STATUS – RESULTS



Correlation index

This summary index is built as the sum of vegetation status index and 112-calls index. High values indicates the simultaneous presence of critical vegetation status and critical number of 112-emergency calls.

The index may give an indication for areas where a negative vegetational trend may be due to the presence of Covid-19 hotspots.

DETECTION OF POSSIBLE COVID-19 HOTSPOTS AND THEIR CORRELATION WITH VEGETATION STATUS – LIMITS AND POSSIBLE IMPROVEMENTS

LIMITATIONS

- A call to 112 cannot be considered equivalent to a certified case of Covid-19.
- Vegetation anomalies detected by remote sensing may not be caused by treatments failures or shortage of seasonal workforce due to the Covid-19 outbreak.
- No information about workforce living areas with respect to agricultural working areas. The assumption is that crops and orchards in a commune are treated by people living in the same commune.

IMPROVEMENTS

- Call Detail Records are needed to assess the mobility trends in the area and related anomalies during the lockdown (a march-september time window for 2019 and 2020 has been evaluated as minimum required time-series).
- 112 emergency calls dataset may be updated to September 2020.
- Covid-19 data (affected population, deaths…) may be provided, aggregated at commune level.
- Negative deviation in phenological parameters for crops can be used instead of area no more detectable as crop, in order to have a more homogenous measure of vegetation status.

Possible exploitations:
support to annual drought localization and damage evaluation (1)

- Multiannual Crop masks at national level (winter/summer crops, permanent through multitemporal Sentinel data (2016-2020)
- Multitemporal MODIS NDVI collection at smaller scale
- NDVI spatialisation at larger scale (Sentinel based) on crop mask
- Multiannual trend evaluation
- 2020 situation assessment and gap analysis
- Correlation with drought limitation for soil classes (ancillary Meteo model and soil map necessary)
- New agronomic plans for future sustainability and local adaptation (e.g. move from rainfed maize to other, change varieties, cultivars, etc)

Possible exploitations:
support to European Common Agriculture Policy (CAP) introduction to: Integrate Administrative Control System, after TAIEX meetings (2)

- LPIS (Land Parcel Identification System) building/updating existing data: cadastral/property/agronomic land use overlapping at very large scale (airborne or VHR satellite)
- Agronomic land use parcels multiseasonal/multiannual analysis by Sentinel processing and classification (vector of parcels necessity)
- Real status of permanent/arable cultivations, at parcel level
- Thematic-administrative data base creation, always updated, aimed to: periodic land change, abandoned parcels, damaged parcels, focused subsidies distribution to single farmers (e.g. agro-industry necessities, Covid-19 support), geo-market analysis along the season, planning of resilience to Climate changes, etc

Support to annual drought localization on Moldova or state portion (agricultural southern areas)

Data:

- Multitemporal Sentinel data (2017-2020)
- Multitemporal MODIS data (2017-2020)
- Existing maps as ancillary info to be used (geo-info on irrigated/non irrigated land is a pre-requisite)

Method:

- Multiannual Crop masks at national level (permanent, pasture, winter/summer crops)
- Multitemporal analysis of MODIS data
- Multitemporal analysis at crop mask level

Output:

- Multitemporal drought conditions evaluation

Support to annual drought localization on Moldova or state portion (agricultural southern areas)

Additional:

- refinement specialization considering meteo and soil classes (chenozem-soil occupies the majority of Moldova, an advantage)
- Possible damage evaluation linked to different cultivation macro-classes/types, also through climate analysis and scenario evolution
- Support for new agronomic plans (policy justification) for future sustainability and local adaptation (e.g. move from rainfed maize to irrigation areas, other crops, change varieties, cultivars, type of cultivation methods, etc)